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An Investigation of the Validity of Selected Submaximal Field Tests to Estimate Aerobic Capacity in Untrained Females

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AN INVESTIGATION OF THE VALIDITY OF SELECTED SUB-MAXIMAL FIELD TESTS TO ESTIMATE AEROBIC CAPACITY IN UNTRAINED FEMALES

BY

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CAPACITY IN UNTRAINED FEMALES

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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YOU CANNOT TEACH A PERSON ANYTHING:

YOU CAN ONLY TEACH HIM TO FIND IT WITHIN HIMSELF.

Galileo

DEDICATION

THIS STUDY IS DEDICATED TO MY PARENTS,

THE FIRST AND MOST LOVING TEACHERS I HAVE EVER HAD.

ACKNOWLEGEMENTS

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A sincere appreciation is expressed to those people who made this year in South Dakota a year of growth and new experiences.

Thank you all,

BAM

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The purpose of this investigation was twofold: (1) to determine the validity of selected submaximal field tests used to estimate aerobic capacity, and (2) to determine the association of maximal oxygen consumption with the performance of selected submaximal field test. Eighteen females ($\overline{X}$ = 19.4 yrs) volunteered to be Ss. Prior to the first two field tests, anthropometric data of ht and wt were collected and %BF, FW, and FFW were computed from skinfold measurements. The field tests investigated were the 12 min run, the 600 yd run, and the QCST. All measurements were analyzed for reliability and reproducibility by the use of a Pearson Product-Moment correlation technique and paired t-tests. The field test performances and estimations of max $\dot{V}O_2$ (l/min and ml/kg/min) were compared with the max $\dot{V}O_2$ estimated by the duration of the Balke-Ware Treadmill Test to determine validity. There were no sig diff between max $\dot{V}O_2$ estimated from the 12 min run and the QCST. There was a sig diff ($\underline{p} < .05$) found between the max $\dot{V}O_2$ (l/min and ml/kg/min) estimated by the Balke-Ware Treadmill Test and that estimated by the 600 yd run. No sig relationships were found between the performance scores and max $\dot{V}O_2$ estimated from the Balke-Ware Treadmill Test. Within the limitations of this investigation, it was concluded that the performance scores from the 12 min run, the

600 yd run, and the QCST did not accurately reflect the individual's aerobic capacity.

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CHAPTER I

INTRODUCTION

Significance of the Study

An important aspect of physical education today is the assessment of circulorespiratory fitness; that is, the ability of an individual's circulorespiratory system to meet the body's demands for oxygen during physical exertion. Results of research in the area of exercise physiology indicate that the measurement of maximal oxygen consumption is the most objective method of determining an individual's circulorespiratory fitness (Taylor, Buskirk and Henschel, 1955; Mitchell, Sproule and Chapman, 1958; Rowell, Taylor and Wang, 1964; Cooper, 1968; Karpovich and Sinning, 1971; de Vries, 1974; Mathews and Fox, 1976; Morehouse and Miller, 1976). The maximal oxygen consumption (max $\dot{V}O_2$) test is widely recognized as the most valid measure of aerobic capacity, but it requires extensive laboratory equipment, specially trained personnel, and motivated subjects. For the assessment of circulorespiratory fitness to be of value in the field, physical educators should have at their disposal a submaximal performance based test which is easily administered and yields an accurate estimation of an individual's aerobic capacity. Of primary concern to the physical educator should be the validity of the field test when it is compared with a clinical test of oxygen consumption.

Purpose of the Study

The primary purpose of this investigation was to determine the validity of selected submaximal field tests used to estimate aerobic capacity. A secondary purpose was to determine the association of maximal oxygen consumption with the performance of selected submaximal field tests.

Hypotheses

The following were hypothesized for this study:

1. It was hypothesized that there would be no significant differences between maximal oxygen consumption and aerobic capacity estimated from selected submaximal field tests.

2. It was hypothesized that there would be a significant relationship between performance scores from selected submaximal field tests and max $\dot{V}O_2$ estimated from the duration of the Balke-Ware Treadmill Test.

Scope

The subjects for this study were volunteer female students from the South Dakota State University (SDSU) Fitness and Lifetime Activity Physical Education Program during the Spring Semester, 1979 (N = 18). They had not been involved in any type of training program for at least six months prior to the testing for this study. Additionally, they were not engaged in any type of regular physical activity during the testing.

The four variables measured in this study were the subjects' performance on the following:

1. 600 yard run test

2. 12 minute run test

3. Queens College Step Test

4. Balke-Ware Treadmill Test.

All the running tests were administered on the 220 yard Astroturf Resilient indoor track located in the South Dakota State University Physical Education Center. The bleacher steps in Frost Arena of the Physical Education Center and the Intramural Building were used to administer the Queens College Step Test. The treadmill, gas collecting and gas analyzing equipment in the SDSU Human Performance Laboratory were used to assess the maximal oxygen consumption of each subject.

The 600 yard run test was administered as outlined in the AAHPER Youth Fitness Test Manual (1976). The 12 minute run was conducted as described by Cooper (1968). The Queens College Step Test was administered in accordance with the instructions of McArdle et al. (1973). The Balke-Ware Treadmill Test (1959) was used for the assessment of max $\dot{V}O_2$.

Limitations

This investigation was limited by the following conditions:

1. Only volunteers from the non-major physical education classes at SDSU were used as subjects.

2. There was no certainty that the subjects tested were highly motivated during the testing.

3. Each individual's activity was not supervised between testing sessions.

4. During the field tests, it was not possible to control the other acitivities in Frost Arena, which may have influenced the performance of the subjects.

Definition of Terms

The following terms are defined for use in this investigation:

1. Circulorespiratory fitness. Circulorespiratory fitness is the ability of the circulorespiratory system to transport oxygen from the atmosphere to the working muscles during physical activities which require sustained effort (Shepard and Lavallee, 1978).

2. Field test. A field test is a performance based test used to estimate an individual's circulorespiratory fitness, requiring equipment that is readily available to the physical educator. This type of test is an alternative that can be used in the gymnasium when the equipment, time and personnel needed for a treadmill test are not readily available.

3. Maximal oxygen consumption (max $\dot{V}O_2$). Maximal oxygen consumption is the maximal rate at which oxygen can be utilized per minute during exercise (Mathews and Fox, 1976). Max $\dot{V}O_2$ is a measure of the subject's physical work capacity (PWC) (deVries, 1974). Measured max $\dot{V}O_2$ refers to the oxygen consumed as measured by open circuit methods while performing on the treadmill.

4. Submaximal test. A submaximal test is a test which has an individual exercising at less than maximal intensity. It does

not place undue stress on an individual, does not require the high levels of motivation required for maximal exercise, and does not require complex, direct measurements of oxygen consumption (Lamb, 1978).

5. Untrained females. Untrained females are those females who have not been involved in any type of regular vigorous activity or training program for six months prior to this investigation.

CHAPTER II

REVIEW OF RELATED LITERATURE

The purpose of this investigation was to determine the validity of selected submaximal field tests used to estimate aerobic capacity. Baumgartner and Jackson (1975) have suggested correlating the measures of the test in question with measures from a valid and recognized instrument. The World Health Organization convened an international committee in 1967, to determine a reference standard of circulorespiratory fitness. The committee determined that the optimum procedure for determining an individual's maximal oxygen uptake in the laboratory is continuous uphill treadmill running. The committee found that the limiting factors on the treadmill were the result of central (general) exhaustion while the bicycle ergometer test was limited by factors of localized exhaustion such as pain or weakness in the quadriceps (Shepard <u>et al</u>., 1968). Since laboratory determination of maximal oxygen consumption is impractical for large groups of individuals, efforts have been made to develop field tests that accurately estimate max $\dot{V}O_2$. The review of literature is subdivided into the following two categories: studies using males as subjects, and studies using females as subjects.

<u>Studies Using Males as Subjects</u>

Attempts to develop a valid test to measure circulorespiratory fitness have not been a recent phenomena. Since the early part of the 20th century, there have been attempts to develop a simple, practical, and valid method for the assessment of circulorespiratory fitness. One of the earlier tests was developed by Barach (1914) to estimate the functional capacity of the heart. Using 289 males, ages 15 through 30 years, as subjects, the investigator developed an energy index, which represented the total effort exerted by the cardiovascular system. Barach considered the systolic blood pressure as the energy factor in the peripheral resistance. The energy index was determined by summing the systolic and diastolic pressures and then multiplying the sum by the resting heart rate. This method was only applied to an individual in a resting state. Schneider (1920) developed a cardiovascular rating system which included the following factors: (1) resting pulse rate, (2) the increase in pulse rate on standing, (3) the standing pulse rate, (4) the exercise pulse rate, (5) the decrease in pulse rate after exercise, (6) the normal systolic blood pressure, and (7) the postural changes in systolic blood pressure. This rating system was applied to 54 aviators who were found to be physically unfit by medical examinations. The results of the rating indicated that a score of nine or less, on a scale of -10 to 18, was characteristic of a physically unfit man.

Tuttle (1931) developed a pulse-ratio test to determine an individual's cardiovascular fitness. The pulse-ratio was determined by dividing the resting pulse rate for one minute by the pulse rate for two minutes after exercise. As a standard exercise, Tuttle chose stepping on and off a 13 inch stool. To vary the amount of work performed, the rate of stepping and the duration of the test was changed. Tuttle adopted 2.5 as the standard pulse-ratio. It was shown that this ratio could be attained by the majority of individuals when performing a moderate amount of work. Tuttle based the pulse-ratio on the existing knowledge of the heart's response to exercise.

At the request of Dr. Frederic Brush of the Burke Foundation Hospital, McCurdy and Larson (1935) devised a test for the measurement of organic efficiency for the prediction of physical condition. Brush believed that this would aid in the determination of the functional fitness of patients leaving the hospital and returning to work. Using 49 male varsity swimmers as the criterion of good condition, 77 male infirmary cases as the criterion of poor condition, and 286 male freshmen representing the average condition as subjects, the investigators devised a test battery which contained the following items: (1) the sitting diastolic pressure, (2) breath holding 20 seconds after exercise, (3) the difference between normal pulse rate and pulse rate two minutes after exercise, (4) the sitting pulse pressure, and (5) the standing pulse pressure. The investigators determined that to be of practical use, a short, simple, and accurate method of scoring was needed. For each subject, the raw score of each test was converted to a T-score. This score was then multiplied by its proper weighting (which had been determined by the investigators) and the scores of the five tests were added together to obtain the final score. This final score was used to determine the condition rating of the individual.

The Harvard Step Test was developed by Brouha (1943) to assess the ability of young men to perform hard muscular work. Brouha chose bench stepping as a standard exercise that a person could not perform in a steady state for more than a few minutes. Two factors which were taken into account were the length of time the exercise could be sustained and the deceleration of the heart rate after exercise. The test consisted of having a subject step up and down on a 20 inch platform 30 times per minute for five minutes unless the subject stopped from exhaustion before the time had elapsed. The pulse was counted from 1 to 1.5, 2 to 2.5, and 3 to 3.5 minutes after the exercise stopped. The test score was equal to the duration of the exercise in seconds multiplied by 100, divided by two times the sum of the pulse counts in recovery. The investigator stated that the step test gave results comparable to those obtained on the treadmill and bicycle ergometer, and was based on the same physiological principles. Brouha pointed out that as many men could be tested in ten minutes as there were observers available to count pulse rates.

Gallagher and Brouha (1943) modified the Harvard Step Test for testing the physical fitness of boys. Due to the wide range of sizes of boys from 12 to 18 years of age, the investigators decided that it was desireable to divide the boys into two groups on the basis of body surface area. A nomographic chart was developed to determine the body surface area based on the height and weight of the subject. The exercise consisted of stepping up and down at the rate of 30 times per minute on an 18 inch platform for the smaller boys and on a 20 inch platform for the larger boys. The duration of the exercise was set at four minutes unless the subject stopped from exhaustion earlier than four minutes. The test was scored the same as the Harvard Step Test:

$$\text{INDEX} = \frac{\text{duration of exercise in seconds x 100}}{\text{2 x the sum of the pulse counts in recovery}}.$$

In 1945, Carlson developed the Fatigue Curve Test to assess an individual's state of physical condition. Carlson used spot running as the exercise to produce a workload since he believed that spot running offered a fair evaluation of work relative to the subject's weight. The investigator demonstrated the use of the Fatigue Curve Test using 200 United States Army soldiers. The subject lifted and lowered his feet alternately, just far enough to clear the floor, as fast as possible for ten seconds. The subject counted the number of right foot contacts and recorded them for each ten second inning of work. The entire test consisted of ten innings of ten seconds of work with ten seconds of rest between each inning. Carlson stated that fatigue would cause a drop in the number of repetitions per inning if the subjects were maximally stressed. To provide an index of condition, pulse rate measurement intervals were established. These included: (1) before exercise, (2) ten seconds after the exercise was terminated, (3) after two minutes of rest, (4) after four minutes of rest, and (5) after six minutes of rest. The ten innings of work were plotted with the number of steps per inning on the ordinate to graphically depict the fatigue curve.

Montoye (1951) attempted to evaluate the research that had been conducted on breath holding ability as a measure of physical fitness. The researcher concluded that maximal breath holding ability was relatively inefficient in differentiating between healthy subjects at differing levels of physical fitness. It was also concluded that there was little evidence of any correlation between various indexes of physical fitness and breath holding ability.

Åstrand and Ryhming (1954) introduced a nomogram to calculate an individual's aerobic capacity (l/min) from a knowledge of heart rate and oxygen consumption or work level attained during a submaximal test. The nomogram was based primarily on the performance of 27 male and 31 female well trained subjects, ages 20 to 30, on submaximal and maximal tests of oxygen consumption. The investigators plotted the aerobic capacity calculated from the nomogram versus the maximal oxygen intake determined during maximal tests on the treadmill or the bicycle ergometer to illustrate the relationship between the two. No correlation coefficient between max $\dot{V}O_2$ determined during maximal tests and the max $\dot{V}O_2$ estimated from the nomogram was reported. The investigators recommended that the oxygen consumption be determined during a submaximal workload (i.e., step test, treadmill, or bicycle ergometer). The estimated aerobic capacity was determined according to the workload on the bicycle ergometer or the subject's weight, and the subject's pulse rate after exercise. Oxygen intake (aerobic capacity) values were presented for healthy, well trained males and females between 20 and 30 years of age.

Taylor, Buskirk and Henschel (1955) devised a maximal oxygen intake test using a motor driven treadmill. The investigators stated that the maximal oxygen intake of an individual offered the possibility of precisely determining one of the limiting factors in an endurance performance associated with a high level of energy expenditure. Two methods of eliciting the maximal oxygen intake were studied. One method of eliciting the maximal oxygen intake was increasing the speed of the treadmill while the grade of the treadmill remained constant (0%). The other method entailed maintaining the treadmill at seven miles per hour and increasing the treadmill grade by 2.5% increments until the oxygen intake value became constant. The investigators chose seven miles per hour since it was the slowest speed at which all subjects needed to maintain a running stride and was slow enough so that a wide range of maximal oxygen intakes could be tested. The data reported in the study were obtained from several experiments. The subjects were 40 conscientious objectors who were studied under a variety of stresses, 27 soldiers who were subjects in short term studies of acute caloric restriction, and 46 students at the University of Michigan who volunteered. All subjects were males, between the ages of 18 and 35, who had passed a rigorous physical examination and were considered in good health. From the results of the experiments, the investigators concluded that raising the grade while the treadmill speed remained constant was the most satisfactory method of increasing the workload to attain a maximal oxygen intake. As an explanation, Taylor et al. suggested that a larger muscle mass was being used in uphill running and that this would increase the oxygen uptake, provided that the circulo-respiratory system could provide the oxygen. It was also found that the room temperature and the length of the warm up before the treadmill test apparently influenced the maximal oxygen consumption rate.

Mitchell, Sproule and Chapman (1958) slightly modified the treadmill test developed by Taylor et al. (1955). Mitchell et al. constructed a treadmill test that could be administered in one day, using 65 males as subjects. Thirty-six of the subjects were between 20 and 29, eighteen between 30 and 39, eight between 40 and 49, and three of the subjects were over 50. For normal subjects, a ten minute warm up period on the treadmill (three miles per hour at a 10% grade) was followed by a ten minute rest. The first phase of the test consisted of having the subject run at six miles per hour on a 0% grade. Expired air was collected for analysis during the last minute of a 2.5 minute run. The subject rested for ten minutes and then ran at six miles per hour on a 2.5% grade. This process of increasing the grade by 2.5% increments was continued until the maximal oxygen intake per minute leveled off.

Åstrand and Saltin (1961a) investigated the extent the duration of exercise influenced the determination of maximal oxygen intake, using four males and one female as subjects. The results of this study indicated that the time required to establish a plateau for oxygen consumption during exercise depended on the workload. The investigators stated that when respiratory and circulatory functions were measured, the workload should be applied for at least five minutes so the body could adapt to the stress. After a ten minute warm up period, the investigators found that about two minutes of very heavy exercise were enough to adjust the oxygen transporting system in young, healthy, well trained subjects to obtain the maximal oxygen intake. Åstrand and Saltin found that with a workload that could be maintained for four to five minutes, or longer, there might be further increases in oxygen uptake beyond those found at two minutes of heavy exercise. The investigators suggested using a repetition of experiments to test aerobic capacity so that the most accurate value could be determined.

In another study, Åstrand and Saltin (1961b) investigated the effect of various types of muscular activity on the maximal oxygen intake and heart rate. Using six males and one female as subjects, the following types of exercises were studied: (1) cycling on a bicycle ergometer in a sitting position, (2) cycling on a bicycle ergometer in a supine position, (3) simultaneous arm and leg work on bicycle ergometers, (4) running on a treadmill, (5) skiing, (6) swimming, and (7) arm work (cranking). The investigators found that the maximal oxygen intake values were slightly higher in uphill treadmill running than cycling, cycling plus cranking, and skiing. For these exercises, similar heart rates were obtained. The other exercises yielded maximal oxygen intake values that were at least 15% lower than those obtained with running and cycling. The investigators concluded that the aerobic capacity and maximal heart rate were superior in maximal treadmill running or cycling among well trained subjects.

In a study conducted for the Civil Aeromedical Research Institute, Balke (1963) found that only during runs between 12 and 20 minutes does an individual achieve a pace which accurately reflects aerobic capacity. Balke found that the 12 minute run estimate slightly exceeded the maximal oxygen intake measured on the treadmill while the 20 minute run estimate fell below the measured max $\dot{V}O_2$.

deVries and Klafs (1965) evaluated the predictions of maximal oxygen intake from submaximal tests using measured max $\dot{V}O_2$ as the criterion of validity. The submaximal tests evaluated were: (1) the Sjostrand-Wahlund test of physical working capacity, (2) a modification of the Sjostrand test using bench stepping instead of a bicycle ergometer, (3) the Harvard Step Test, (4) the Progressive Pulse-Ratio Test, (5) a three minute modification of the Delta Respiratory Quotient Test, and (6) the Åstrand-Ryhming nomogram. For the subjects tested in this study, 16 male Physical Education majors, the highest predictive values of maximal oxygen consumption were derived from the Åstrand-Ryhming nomogram and the Sjostrand-Wahlund test. The investigators stated that those tests in which the heart rate during a measured workload was the basis of prediction had a slightly greater predictive value than those which used the heart rate during the recovery period. From the results of this study, the investigators concluded that maximal oxygen intake can be predicted with a reasonable error of prediction from submaximal tests.

In the American Alliance of Health, Physical Education and Recreation (AAHPER) Youth Fitness Test, the 600 yard run test has been used to estimate the circulorespiratory fitness of children from ten to 18 years of age. Falls, Ismail and MacLeod (1966) used the AAHPER Youth Fitness Test items to estimate the aerobic capacity of 87 adult males between the ages of 23 and 58 years. With all seven independent variables of the Youth Fitness Test included in a multiple regression equation, a multiple correlation coefficient of R = .760 was obtained for the estimation of maximal oxygen uptake (ml/kg/min). The investigators concluded that maximal oxygen consumption (ml/kg/min) could be estimated with reasonable validity from the subject's performance on the motor fitness items of the AAHPER Youth Fitness Test. It was also concluded that the single best estimator of maximal oxygen uptake among the test items was the 600 yard run. However, Balke (1963), Olree (1965), Metz and Alexander (1970) have indicated that the 600 yard distance is insufficient to measure aerobic endurance.

Corrol (1967) investigated the ability of the AAHPER Youth Fitness Test items to predict max $\dot{V}O_2$ in young males, 11 years old. Using the 600 yard run time (seconds) and the subject's weight (pounds), Corrol developed a regression equation which was significant ($p \leq .05$) with an $R = .78$ and an $SEE = \pm 4.32$ ml/kg/min. Although the regression equation was found to be significant, Corrol stated that the efficiency of maximal oxygen intake prediction from the AAHPER Youth Fitness Test was too low for individual prediction and only indicates a group trend.

Cooper (1968) investigated the relationship between the maximal oxygen consumption estimated from a 12 minute run test and the max $\dot{V}O_2$ measured on the treadmill, using 115 male Air Force personnel as subjects. The investigator found the relationship signifi cant ($r = .897$). Cooper concluded that the high correlation of the maximal oxygen consumption estimated from the run score with that measured on the treadmill made it possible to estimate, with considerable accuracy, an individual's maximal oxygen consumption from the results of the 12 minute run test. The investigator stated that the test was readily adaptable to large groups, required minimal equipment, and appeared to be a better indicator of circulorespiratory fitness than the 600 yard run. Cooper stated that due to the high correlation with maximal oxygen consumption, it could be assumed that the 12 minute run test was an objective measure of physical fitness, reflecting the circulorespiratory status of an individual. According to Cooper, this study indicated that in young, well motivated subjects, field testing could provide a good assessment of maximal oxygen consumption; but the accuracy of the estimate was directly related to the motivation of the subjects.

The findings of Doolittle and Bigbee (1968) revealed a correlation similar to Cooper's, r = .90, using 149 ninth grade boys as subjects. The investigators, using the test-retest coefficient of reliability with nine subjects selected at random, found r = .976. They also concluded that the 12 minute run was a highly reliable and valid indicator of maximal oxygen consumption. Using three divergent ability groups, Kearney and Byrnes (1974) found a significant ($p \leq .05$) r = .63 for the composite group between the oxygen uptake estimated by the Åstrand Bicycle ergometer test and the 12 minute run using 34 college males as subjects. Seven of the subjects were considered non-athletes and non-PE majors and yielded an r = .80 (significant at $p \leq .05$). Group II included ten PE majors and yielded an r = .64 (significant at $p \leq .05$). The third group consisted of 17 varsity cross country runners. With this group, a nonsignificant r = .28 was found between maximal oxygen consumption determined on the bicycle ergometer and that estimated from the 12 minute run distance. The investigators suggested that the trend toward a decreased performance and estimated oxygen uptake as the skill level increased was due to the higher motivation, higher pain tolerance and the greater homogeneity of the skilled runners.

Wanamaker (1969), using 96 male subjects between the ages of 18 and 23, investigated the validity and reliability of the 12 minute run test under four selected motivational conditions. An additional purpose for this study was to determine what difference in performance, if any, was caused by the motivational conditions. The subjects were in two groups, those who volunteered and those who took part in the study to fulfill a class requirement. Each subject ran four times, twice as part of a group and twice as an individual. Pearson Product-Moment correlations were used to determine differences in running performance. The investigator concluded that the 12 minute run was a reliable measure, but due to the relatively low validity coefficients ($r = .22$ to $r = .53$) between measured max $\dot{V}O_2$ and max $\dot{V}O_2$ estimated by the 12 minute run, and high error estimates, the predictive value of the 12 minute run test in terms of maximal oxygen consumption was doubtful. Wanamaker found no significant differences in running performances due to running in a group or as an individual.

Gregory (1970), in a study using 40 well-conditioned males (ages 18-30) as subjects, found a nonsignificant ($p \leq .05$) $r = .66$, between the 12 minute run performance and maximal oxygen intake. The subjects in this study had a mean max $\dot{V}O_2$ value of 51.96 ml/kg/min. Only 6.3% of the Air Force personnel tested by Cooper had higher oxygen uptakes. Gregory concluded that the 12 minute run might be a more valid test of circulorespiratory fitness of unconditioned subjects.

Maksud and Coutts (1971) found a similar correlation of $r = .65$, which was significant ($p \leq .01$), between the 12 minute run and max $\dot{V}O_2$ in 11 to 14 year old boys. The investigators indicated that the low correlation coefficient may have been due to the relatively small (N = 17) and homogeneous group of subjects used. The investigators concluded that the prediction of maximal oxygen consumption from the performance on a twelve minute run test should be approached with some caution when applied to young urban subjects.

In summary, the results of research have indicated that there has been a continuing interest in the development of submaximal tests to assess an individual's circulorespiratory fitness. The earlier research investigated blood pressure, pulse rate changes, breath holding ability, pulse-ratios, and pulse pressure to indicate an individual's level of fitness.

More recently, bench stepping (Brouha, 1943), running 600 yards, and the distance run in 12 minutes have been used to estimate an individual's aerobic capacity. The research has yielded conflicting results. The research of Falls et al. (1966) and Corrol (1967) indicated that the 600 yard run was the most valid indicator of circulorespiratory fitness in the AAHPER Youth Fitness Test while Balke (1963), Olree (1965) and Metz and Alexander (1970) indicated that the 600 yard distance was insufficient to measure aerobic endurance.

Balke (1963) found the 12 minute run estimate of aerobic capacity slightly exceeded the max $\dot{V}O_2$ value obtained on the treadmill. Cooper (1968) stated that the 12 minute run was an accurate predictor of max $\dot{V}O_2$ in well motivated subjects. The findings of

Doolittle and Bigbee (1968) and those of Kearney and Byrnes (1974) were similar to the results of Cooper's (1968) study. The research results of Wanamaker (1969), Gregory (1970), and Maksud and Coutts (1971) indicated that the 12 minute run was not a valid predictor of max $\dot{V}O_2$.

Studies Using Females as Subjects

One of the first studies that dealt with the physical efficiency of college women was undertaken by Tuttle and Frey (1930). Tuttle and Frey adapted the Tuttle pulse-ratio test to assess the cardiovascular fitness of college women. The investigators determined that the standard exercise should be stepping on a 13 inch stool at a uniform rate for a period of one minute. The amount of work performed by the subject was varied by changing the rate of stepping. As in the Tuttle pulse-ratio test, the standard pulse-ratio was 2.5. The percent efficiency of the individual was determined by:

$$\frac{\text{Number of steps required for 2.5 ratio} \times 100}{30}.$$

Using 19 college women as subjects, Tuttle and Frey found that the variation in efficiency ratings of individuals who were not involved in systematic training, was between 9% and 13%. The investigators stated that when the variation was greater or less, there appeared to be some special circumstances which accounted for it.

Using 296 females, 17 to 21 years of age, as subjects, Clarke (1943) modified the Harvard Step Test for use by college women. The investigator devised a test to measure the ability of the body to recover after strenuous physical activity. The workload consisted of stepping 30 times per minute for four minutes on an 18 inch bench. Clarke developed a nomogram for calculating the subject's index of physical fitness based on the sum of the pulse rates taken 1 to 1.5, 2 to 2.5, and 3 to 3.5 minutes after exercise with the duration of the exercise in seconds.

In a study mentioned earlier, Åstrand and Ryhming (1954) developed a nomogram to calculate an individual's aerobic capacity (l/min) from a knowledge of heart rate and oxygen consumption (or work level) reached during a test with a submaximal rate of work. Using a bicycle ergometer at 600 kgm/min and 900 kgm/min, the percent error between maximal oxygen intake calculated from the nomogram and that determined from cycling was 14.4% and 9.4%, respectively, for females. The best results were obtained when the heart rate attained a level between 125 and 170 beats per minute. By use of the nomogram, an individual's maximal oxygen uptake (l/min) could be estimated from a submaximal workload, without the use of extensive equipment or specially trained personnel.

Another modification of the Harvard Step Test was developed by Sloan (1959) to make it more suitable for women. The investigator compared the fitness indexes of two groups (N = 15 and N = 16) of healthy young (17-21 year old) women performing the step test on steps of various heights (16", 17", 18", 20") with the fitness indexes of a corresponding group (N = 42) of young men performing the test on a 20 inch bench. The investigator stated that the 20 inch bench often produced local fatigue of the leg muscles before the subject had reached her aerobic capacity. Sloan found that a step of 17 inches was suitable for women performing the Harvard Step Test. The investigator concluded that with a 17 inch step, the standards of performance for men on a 20 inch bench could be applied with the same validity.

Using one female and four males as subjects, Astrand and Saltin (1961a) investigated the duration of exercise and how it influenced the determination of maximal oxygen intake. The investigators stated that the workload should be applied for at least five minutes so the body could adapt to the stress. In a second study, Astrand and Saltin (1961b) used one female and six males as subjects to investigate the effect of various types of muscular activity on maximal oxygen intake and heart rate. The female subject took part in only the cycling and cycling with arms (cranking) tests. No reference was made by the investigators to the results of the female or why she was only included in two tests.

In another effort to modify the Harvard Step Test to make it more suitable for women, Skubic and Hodgkins (1963) modified the test in various ways and then analyzed the different methods for reliability and validity. The investigaors, using 96 females as subjects (ages 12-25), found that a three minute step test, stepping at the rate of 24 steps per minute on an 18 inch bench was a valid and reliable test of the circulorespiratory fitness of girls and women. The results of the study indicated that the modified test clearly differentiated between females in a highly trained, moderately active, or sedentary state.

Burris (1970) investigated the reliability and validity of the twelve minute run as a measure of aerobic capacity of college women. Thirty college females between the ages of 17 and 23 performed three trials of the 12 minute run and two or three trials of a progressive treadmill test. Consistency coefficients were calculated from a two-way ANOVA, yielding .936 for the mean of the trials. Validity was obtained by correlating the 12 minute run performance with the treadmill grade, $r = .772$, with the maximal oxygen consumption during the treadmill test, $r = .736$, and with the optimal work capacity, $r = .732$. On the basis of the results, the investigator concluded that the 12 minute run was a reliable and valid measure of the aerobic capacity of college women.

McArdle et al. (1972) investigated the reliability and interrelationships between maximal oxygen consumption, physical work capacity, and step test scores in college females ($N = 41$). The investigators concluded that the recovery heart rate score from a three minute step test of moderate intensity was a reliable ($r = .92$) and valid indicator of the maximal oxygen intake of college women. The validity coefficient between the heart rate recovery score and max $\dot{V}O_2$ (ml/kg/min) was $r = -.75$. This coefficient was significantly ($p \leq .06$) higher than the $r = -.64$ obtained when the same subjects took the Skubic-Hodgkins Step Test.

The investigators also found that the heart rate recover scores on the Queens College Step Test were independent of body weight ($r = .15$) while a low ($r = .38$) but statistically significant ($p \leq .05$) correlation was found between the heart rate recovery score for the Skubic-Hodgkins Step Test and body weight.

Katch et al. (1973) conducted a study of the validity of the 12 minute run for college females ($N = 36$) using max $\dot{V}O_2$ determined on the treadmill as the criterion of validity. The investigators found a significant correlation ($r = .67$) between the 12 minute run and maximal oxygen consumption in ml/kg/min. Using Cooper's regression equation to predict the oxygen consumption from the 12 minute run scores of men, Katch et al. determined that the average maximal oxygen consumption of the female subjects was underestimated by 18%. Seventeen of the subjects from the sample had their body composition determined by hydrostatic weighing methods. With these subjects ($n = 17$), there was a significant ($p \leq .05$) relationship ($r = .57$) between max $\dot{V}O_2$ (l/min) and the distances run. When the max $\dot{V}O_2$ was expressed in ml/kg/min, the correlation increased to $r = .76$. Since lean body weight was found to correlate highly with both max $\dot{V}O_2$ (l/min) and the 12 minute run distances ($r = .49$), the investigators controlled the influence of lean body weight by a partial correlational technique. The partial correlation significantly reduced the observed correlation between maximal oxygen consumption and running performance to $r_{12.3} = .35$. Percent body fat was also partialled out from the correlation between max $\dot{V}O_2$ and the run scores, yielding a similarly low and nonsignificant correlation. The investigators concluded that the 12 minute run test was not a good predictor of individual differences for the sample studied since approximately 55% of the variance in max $\dot{V}O_2$ was unexplained by a knowledge of the 12 minute run score.

Katch et al. (1973) pointed out that Cooper's high correlation ($r = .897$) was due to a wide age range (17 to 54 years), a large variation in max $\dot{V}O_2$ values (31 to 59 ml/kg/min), and a large variation in run scores (1.11 to 2.13 miles). Katch et al. (1973) reported that the large variations would have the effect of inflating the value of the correlation coefficient, primarily since age is significantly related to max $\dot{V}O_2$. The investigators stated that since Cooper did not report the correlation between age and max $\dot{V}O_2$, it was not possible to evaluate the influence of age on the correlation between max $\dot{V}O_2$ and 12 minute run scores by the use of a partial correlation. Katch et al. (1973) proposed that if this had been done, Cooper's correlation of $r = .897$ would have been reduced substantially.

In summary, the research of the validity of submaximal field tests for women has not been extensive. Researchers have investigated the pulse-ratio test, step tests, and the 12 minute run. Tuttle and Frey (1930) undertook one of the first studies that dealt with the physical efficiency of college females. The investigators developed a pulse-ratio test to assess the cardiovascular fitness of females.

In 1943, Clarke modified the Harvard Step Test to make it more suitable for women by decreasing the duration of the test and lowering the height of the bench. Sloan (1959), Skubic and Hodgkins (1963), and McArdle et al. (1972) made further modifications of the step test. When McArdle et al. (1972) compared the Queens College Step Test with the Skubic-Hodgkins Step Test, it was found that the heart rate recovery score of the Queens College Step Test was independent of body weight while the relationship of the heart rate recovery score of the Skubic-Hodgkins Step Test and body weight were statistically significant ($p \leq .05$).

Burris (1970) and Katch et al. (1973) investigated the validity of the 12 minute run and the research results yielded different conclusions. Burris (1970) concluded that the 12 minute run was a reliable and valid measure of aerobic capacity while Katch et al. (1973) concluded that the 12 minute run was not a good predictor of aerobic capacity.

Summary

There have been many methods devised to assess an individual's circulorespiratory fitness. Some of the earlier research investigated blood pressure, pulse rate changes, breath holding ability, pulse-ratios, and pulse pressure as indexes of fitness. One of the first investigations using females as subjects was conducted by Tuttle and Frey (1930). The investigators recognized the need for a method of assessing the circulorespiratory fitness of women and adapted the Tuttle pulse-ratio test for use by females.

Shortly after Brouha (1943) introduced the Harvard Step Test, Clarke (1943) modified the test for use by women. The investigator shortened the length of the test to four minutes, lowered the bench step to 18 inches, and maintained the rate of stepping at 30 times per minute. Clarke devised a nomogram for use with the revised test to calculate the subject's index of physical fitness based on the sum of the pulse rates taken 1 to 1.5, 2 to 2.5, and 3 to 3.5 minutes after exercise and the duration of the exercise in seconds.

In 1954, Åstrand and Ryhming developed a nomogram to calculate an individual's aerobic capacity from a knowledge of heart rate and workload. The nomogram was designed for use by both males and females. The workload could be provided by a step test or a bicycle ergometer. By use of the nomogram, an individual's maximum oxygen uptake (l/min) could be estimated from a submaximal test, without the use of extensive equipment of specially trained personnel.

Sloan (1959) provided another modification of the Harvard Step Test by lowering the bench height to 17 inches while keeping the rest of the test the same as the original. The investigator concluded that with a 17 inch step, the standards of performance for men on a 20 inch bench could be applied to women with the same validity.

Åstrand and Saltin conducted two studies; one investigated how the duration of exercise influenced the determination of maximal oxygen consumption (1961a) and the other study, the effects of various types of muscular activity on maximal oxygen intake and heart rate (1961b). Both studies used a small number of subjects ($N = 5$ and $N = 7$, respectively) and each study had only one well trained female subject. Based on the results of these two investigations, it would be difficult to make any inferences to the female population. Also, in the second study, data for the female subject was only reported for cycling and cycling plus arms. No explanation was offered by the investigators as to why this was done.

A third effort to modify the Harvard Step Test for use by women was conducted by Skubic and Hodgkins (1963). The investigators concluded that stepping at the rate of 24 steps per minute for three minutes, on an 18 inch bench was a valid and reliable test of the circulorespiratory fitness of girls and women.

In 1966, Falls, Ismail and MacLeod used the results from the AAHPER Youth Fitness Test to estimate the aerobic capacity of adult males. The investigators found the 600 yard run to be the best indicator of circulorespiratory endurance in the Youth Fitness Test. However, Balke (1963), Olree (1965) and Metz and Alexander (1970) indicated that the 600 yard distance is insufficient to measure aerobic endurance.

In a study by McArdle _et al_. (1972), another variation of the step test for college women was devised, the Queens College Step Test. In this study, the subjects also performed the Skubic-Hodgkins Step Test. A significantly higher ($p \leq .06$) correlation coefficient

($r = -.75$) was obtained when the measured max $\dot{V}O_2$ (ml/kg/min) was correlated with the heart rate recovery score from the Queens College Step Test than when the max $\dot{V}O_2$ (ml/kg/min) was correlated with the Skubic-Hodgkins Test ($r = -.64$).

The remainder of the studies reviewed dealt with the validity and reliability of the 12 minute run. Cooper (1968) investigated the relationship between the maximal oxygen consumption estimated from a 12 minute run test and the max $\dot{V}O_2$ measured on the treadmill, finding a correlation of $r = .897$. On the basis of the high correlation, Cooper concluded that the 12 minute run was an objective measure of physical fitness as reflected by the circulorespiratory status of an individual. Doolittle and Bigbee (1968) found a correlation ($r = .90$) similar to that of Cooper's study and concluded that the 12 minute run was a highly reliable and valid indicator of maximal oxygen intake. Kearney and Byrnes (1974) also concluded that the 12 minute run was a reliable and valid measure of circulorespiratory fitness. Burris (1970), using college females as subjects, concluded that the 12 minute run was a reliable and valid measure of the aerobic capacity of college women.

In contrast, Wanamaker (1969), using 96 male subjects, found the 12 minute run to be a reliable measure, but the predictive value of the test in terms of maximal oxygen consumption was doubtful. In a study by Gregory (1970), a nonsignificant ($p \leq .05$) $r = .66$ was found between the 12 minute run performance and maximal oxygen intake. Gregory concluded that the 12 minute run might be a more valid test of the circulorespiratory fitness of subjects in poorer physical condition than the subjects used. Maksud and Coutts (1971) found a similar correlation ($r = .65$) which was significant ($p \leq .01$) between the 12 minute run and max $\dot{V}O_2$ in 11 to 14 year old boys. Even though the relationship was significant ($p \leq .01$), the investigators concluded that the prediction of maximal oxygen consumption from the performance on a twelve minute run test should be approached with caution when applied to young urban subjects.

In a study of the validity of the 12 minute run using college females as subjects, Katch et al. (1973) found a significant correlation ($r = .67$) between the 12 minute run and maximal oxygen consumption (ml/kg/min). Since lean body weight was found to correlate highly with both max $\dot{V}O_2$ (l/min) and the 12 minute run distance ($r = 49$), the investigators controlled the influence of lean body weight by a partial correlation technique. The partial correlation significantly reduced the observed correlation between maximal oxygen consumption and the 12 minute run performance to $r_{12.3} = .35$. The investigators concluded that the Cooper 12 minute run test was not a good predictor of individual differences in max max $\dot{V}O_2$.

The review of literature indicates that there has been a lack of research to validate submaximal tests of circulorespiratory fitness for women. In the studies conducted, the results indicate that there is still some doubt as to the ability of the Queens College Step

Test, the 600 yard run, and the 12 minute run to accurately assess the circulorespiratory fitness of college females.

CHAPTER III

METHODOLOGY

The purpose of this investigation was to determine the validity of selected submaximal field tests used to estimate the aerobic capacity of healthy untrained college females. The results of the three field tests, namely, the 600 yard run, the 12 minute run, and the Queens College Step Test, were compared with the results from the Balke-Ware Treadmill Test. This chapter describes the research design of the investigation, subjects, data collection procedures and methods of data analysis.

Research Design

This investigation was conducted during the 1979 Spring Semester at South Dakota State University in Brookings, South Dakota. Each subject ($N = 18$) completed six tests; three field tests to estimate aerobic capacity (the 600 yard run, the 12 minute run, and the Queens College Step Test), a treadmill test to determine max $\dot{V}O_2$, and two retests which were randomly assigned. The retests ($n = 10$ for the 600 yard run and the Queens College Step Test, $n = 8$ for the 12 minute run and the Balke-Ware Treadmill Test) were used to determine the reliability and reproducibility of the measurements. Only the results from the first tests were used as representative values in the subsequent statistical analyses. The testing order was randomly assigned and the testing was scheduled at times mutually agreeable to each subject and the investigator. The tests were given with at least a one day interval between the testing sessions.

The field tests were administered on the 220 yard Astroturf Resilient indoor track or on the bleacher steps in Frost Arena, with the max $\dot{V}O_2$ assessment made in the Human Performance Laboratory, all located in the Physical Education Center (PEC) at South Dakota State University. The bleacher steps in the Intramural Building, located on the SDSU campus, were also used.

Prior to the administration of each of the first two field tests, selected anthropometric measurements, including height, weight, suprailiac skinfold and triceps skinfold, were measured for each subject. The measurements were collected by the investigator with the aid of trained assistants.

Subjects

The subjects (N = 18) who participated in this study were healthy untrained female students enrolled in the South Dakota State University Fitness and Lifetime Activity Physical Education Program during the Spring Semester, 1979. Eighteen subjects (mean age = 19.4 years) were tested between April 18 and May 11, 1979. The physical characteristics of the subjects are shown in Table I.

The following procedures were used to familiarize the subjects with this investigation:

1. Prior to data collection, each subject was given an explanation of the measurements to be used in this study and asked to read it (Appendix A).

2. Each subject was asked fo fill out a health survey to help determine whether there was any reason that she should not participate in this study (Appendix B).

3. After reading the explanation of the tests and completing the health survey, the subject was asked to read and sign a human consent form (Appendix C).

TABLE I

PHYSICAL CHARACTERISTICS OF THE SUBJECTS (N = 18)

Variable	$\bar{X}$	S	CV	Range
Age (Years)	19.4	0.7	3.6	18.5 - 21.3
Height (cm)	166.1	6.0	3.6	155.3 - 174.5
Weight (kg)	60.2	8.4	14.0	45.2 - 76.0
Body Density[a] (gm/cc)	1.051	.007	0.7	1.039 - 1.063
% BF[b]	20.6	2.7	13.1	15.6 - 25.8
FW (kg)[c]	12.5	3.2	25.6	7.0 - 18.2
FFW (kg)[d]	47.8	5.6	11.7	37.5 - 58.5

[a]computed from the Sloan-Weir (1970) formula for predicting Body Density.

[b]computed from Brozek (1963) formula for determing % Body Fat.

[c] and [d]determined using the computed % Body Fat.

Anthropometric Measurements

Prior to each of the first two test sessions, four anthropometric variables, height, weight, suprailiac skinfold and triceps skinfold, were measured. The skinfold measurements were taken on the right side of the body with Harpenden skinfold calipers. Each anthropometric variable was measured three consecutive times during the two testing sessions. The mean of the three measurements recorded prior to the first test was the representative value for the test and the mean of the three measurements recorded prior to the second test was the representative value for the retest. The test-retest values were used to determine the reliability and reproducibility of the measurement. The first test value was used as a representative value for the anthropometric variable being measured. While being measured, the subject wore only a tee shirt and shorts.

Height. Height was measured while the subject was standing erect, weight distributed evenly on both feet, heels together, eyes looking straight ahead, back against the stadiometer, and arms hanging naturally at the sides. The metal bar was lowered until it touched the top of the subject's head and the height was recorded to the nearest .5 centimeter. After the height was recorded, the subject stepped off the stadiometer and the procedure was repeated two more times (Appendix D).

Weight. Weight was measured while the subject was standing motionless in the middle of the scale's platform. Once the scale stabilized and the weight was recorded, the subject stepped off of the scale and the procedure was repeated two more times. The weight was recorded to the nearest .5 pounds and then converted to kilograms (Appendix E).

Suprailiac skinfold. The suprailiac skinfold was measured as a vertical skinfold over the iliac crest in the mid-axillary line (Sloan and Weir, 1970). The subject was instructed to stand erect with her weight evenly distributed on both feet and the right arm held slightly behind her side. The skinfold was measured three times. The skinfold was regrasped each time a measurement was taken (Appendix F).

Triceps skinfold. The triceps skinfold was measured with the elbow extended. The skinfold was a vertical skinfold on the back of the right arm, halfway between the acromion and olecranon processes (Sloan and Weir, 1970). After grasping the skinfold, the investigator instructed the subject to flex the elbow to make certain that none of the triceps musculature was being grasped. The subject then extended the elbow and relaxed the arm while the measurement was being taken. Each time the skinfold was measured, the skinfold was regrasped (Appendix F).

Body density. The suprailiac and triceps skinfolds were substituted into the Sloan-Weir (1970) formula to determine the body density for the subjects. The formula used was:

Body Density = 1.0764 - .00081 (Suprailiac skinfold) - .00088 (Triceps Skinfold).

The test-retest values of the skinfold sites were used to determine the reliability and reproducibility of the estimation of body density. The first test value was used as the representative body density value.

Percent body fat. Percent body fat was computed from body density values using the Brozek (1963) formula. The formula used was:

Percent Body Fat = (4.570/Body Density - 4.142) x 100.

The body density values computed from the test-retest values of the skinfold sites were used to determine the reliability and reproducibility of percent body fat. The representative body density was used to compute the representative percent body fat value.

Field Tests

600 yard run. The 600 yard run was administered according to the guidelines of the AAHPER Youth Fitness Test Manual (1976). The object of the test was to run the 600 yard distance as quickly as possible. The 220 yard indoor track located in the Physical Education Center at SDSU was marked to indicate the starting line and the finishing line. Only a standing start was allowed. As the subjects were running, they were informed of their lap times at 220 yards and 440 yards. Each subject's score was recorded to the nearest .1 second. Before the 600 yard run, as well as the other field tests, the subjects were allowed to stretch out and warm up until they felt ready to start (Appendix G). The subjects time, in seconds, was substituted into an equation derived by Corrol (1967) to predict oxygen consumption. The equation used was:

X_o (Natural Log O_2 Intake ml/kg/min) = 8.098 - .649 (Natural Log 600 yard Run Time in Seconds) - .208 (Natural Log Weight in Pounds).

This equation has an R = .782 and a SEE = $\pm$4.32 ml/kg/min of oxygen for young (11 year old) males.

12 minute run. The 12 minute run test was conducted according to Cooper (1968). The test was administered on the 220 yard indoor track in the Physical Education Center. The track was divided into four 55 yard segments. The subjects were advised to run at a steady pace to cover the most distance, but walking was permitted. Only a standing start was allowed. During the test, the subjects were informed of their lap times. The score was recorded in laps plus .25 fractions of laps completed during the 12 minutes. This score was converted to miles, to the nearest .01 mile. Two to five subjects performed the test at one time (Appendix H). The subject's score was used to predict oxygen consumption. The estimation was made from interpolation from Cooper's chart (Appendix I).

Queens College Step Test. The Queens College Step Test was administered as directed by McArdle et al. (1973). The test was administered individually on the bleacher steps in the Frost Arena and in the Intramural Building at South Dakota State Uninversity. The test was explained and demonstrated for each subject. After seeing the demonstration, a 15 second practice trial was given to the subject. A three minute rest period followed the practice trial.

The test consisted of stepping continuously at the rate of 22 steps per minute on a 16.25 inch bench for three minutes. Five seconds after the completion of the test, the subject's pulse was monitored by the investigator at the carotid artery for 15 seconds. The 15 second pulse was multiplied by four to obtain the subject's score in beats per minute (Appendix J). To estimate oxygen consumption, the following equation was used:

Estimated max $\dot{V}O_2$ (ml/kg/min) = 65.81 - .1847 (heart rate recovery score)

(McArdle et al., 1973).

Treadmill Test Protocol

Oxygen intake was assessed using the treadmill protocol of Balke and Ware (1959) with a modification by Katch et al. (1973). The subject walked on the treadmill which was set at a speed of 3.3 miles per hour. For the first two minutes, the grade of the treadmill was 0%. After two minutes, the grade was raised to 2%; with each subsequent minute, the grade of the treadmill was increased 1% until the heart rate of the subject reached 180 beats per minute. If the subject could walk at the maximum treadmill elevation (18%), the speed of the treadmill was increased .1 mph/min until the heart rate reached 180 beats per minute. During the testing, the laboratory temperature ranged from 20.0°C to 23.3°C.

The following data were collected for each subject from the treadmill test: (1) heart rate (beats per minutes), (2) oxygen consumption (l/min and ml/kg/min), (3) pulmonary ventilation (l/min),

(4) temperature of expired gas (^{o}C), (5) respiratory exchange ratio (R), and (6) duration of the test (minutes).

When the subject reported to the Human Performance Laboratory, the entire test protocol was explained (Appendix K) and the equipment was adjusted. After answering any questions that the subject may have had, the electrodes were put on and connected to the transmitter. The subject was allowed to stretch, especially the calf muscles, before the test. As a warm up and to become familiar with the treadmill, the subject walked for two minutes on the treadmill at a 0% grade with the speed set at 3.3 miles per hour. After resting for five minutes, the treadmill test began. Throughout the test, the subject was encouraged to do her best.

Oxygen consumption. While walking on the treadmill, the subject breathed through a Modified Otis-McKerrow one way valve which was connected to a Parkinson Cowan Spirometer (CD-4 Dry Gas Meter) to measure expired gas volume and temperature. One minute continuous expired gas volume samples were collected in five liter gas bags as the subject's heart rate approached 170 beats per minute. After the termination of the test, the collected expired gas was analyzed immediately for carbon dioxide and oxygen concentration with the use of a Godart Pulmo-Analyzer (Appendix L). The sodaline in the Pulmo-Analyzer was replaced before each bag of gas was analyzed. Barometric pressure and expired gas temperature were recorded to correct the gas volume measurement to S.T.P.D. (0^{o} centigrade temperature, 760 millimeters atmospheric pressure free of water vapor). The $\dot{V}O_2$ value was computed for the heart rate of the last minute of the treadmill test. To predict max $\dot{V}O_2$, the following equation was used:

$$\dot{V}O_2 \text{ (ml/min)}_{STPD} = v \times w \times (.073 + \frac{oc}{100}) \times 1.8$$

where

v = treadmill speed in meters per minute

w = body weight in kilograms

oc = treadmill angle in percent

1.8 = factor constituting the oxygen requirement in ml/min for 1 meter-kilogram of work (Balke and Ware, 1959).

Heart rate. Heart rate was monitored during each minute of the test using two electrodes which were connected to a telemetric unit (E & M Instrument Co., Inc., Houston, TX). One electrode was placed on the mid-sternum and the second in the fifth intercostal space. The radio signal was received by a Biotelemetry Receiver (E & M Instrument Co., Inc.) and then transmitted to a Physiograph Six, where a printout was recorded. The paper speed for the physiograph was set at 1 cm/sec; therefore, the number of peaks in 6 cm multiplied by ten equaled the heart rate for one minute.

Statistical Analysis of the Data

Test-retest reliability and reproducibility for each of the three field tests and the treadmill test were computed using Pearson Product-Moment Correlation coefficients and paired t-tests (n = 10 for the 600 yard run and the Queens College Step Test, n = 8 for the 12 minute run and the Balke-Ware Treadmill Test). The test-retest reliability and reproducibility for the antropometric variables were also computed using Pearson Product-Moment Correlation coefficients and paired t-tests (N = 18).

To determine if a significant difference existed between max $\dot{V}O_2$ estimated from the Balke-Ware test and the max $\dot{V}O_2$ estimated by the field tests, a One-Way Analysis of Variance (ANOVA) was used. One ANOVA was conducted to determine if a significant difference existed among the means of the max $\dot{V}O_2$ estimation as expressed in l/min and a second when expressed in ml/kg/min. Tuckey's w-procedure was used as a post hoc analysis to determine which groups had significantly different means. The Pearson Product-Moment Correlation technique was used to determine the association between anthropometric variables, performance scores from the field tests and max $\dot{V}O_2$ values. Finally, a stepwise regression technique was used to establish prediction equations that estimated max $\dot{V}O_2$ from field test performance values.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

The primary purpose of this investigation was to determine the validity of selected submaximal field tests used to estimate aerobic capacity. A secondary purpose was to determine the association of maximal oxygen consumption with the performance of selected submaximal field tests.

The analysis of data and discussion of results have been presented in eight parts. The first part includes the reliability and reproducibility of the anthropometric variables, field test scores, and treadmill test results. The second part deals with the performance scores from the field tests. Contained in the third part is the descriptive data obtained from the Balke-Ware Treadmill Test. The fourth part shows the zero-order correlation coefficients between the anthropometric variables, the field test scores, and the max $\dot{V}O_2$ estimated from the treadmill test. Part five contains an ANOVA used as a significance test, with part six being the results of a Tuckey's w-procedure post hoc analysis. The seventh part contains stepwise multiple regression equations to predict max $\dot{V}O_2$ from the performance scores of the 600 yard run, the 12 minute run, and the Queens College Step Test. The eighth part presents a discussion of the results. The raw data on which the statistical analyses were based are presented in Appendix M.

Reliability and Reproducibility of the Data

Anthropometric variables. Pearson Product-Moment Correlation coefficients and paired t-tests (N = 18) (Table II) were used to assess the test-retest reliability and reproducibility of the measurements of height (cm) and weight (kg) in addition to the body density (gm/cc), % body fat, fat weight (kg), and fat free weight (kg) values computed from the suprailiac and triceps skinfolds. The reliability coefficients of all the variables were significant ($r = .98$ to $r = 1.00$, $p \leq .01$) with no significant differences found between the mean of the anthropometric variables for Day 1 and the mean of Day 2. Since no significant differences were found and the measures were reliable, only the measures from the first day were used in the subsequent statistical analyses.

Field test values. The test-retest reliability and reproducibility for the 12 minute run ($n = 8$), 600 yard run ($n = 10$), and the Queens College Step Test ($n = 10$) were assessed by the use of Pearson Product-Moment Correlation coefficients and paired t-tests (Table III). The 12 minute run proved to be a reliable ($r = .97$, significant at $p \leq .01$) but not reproducible test since a significant difference ($t = 4.54$, significant at $p \leq .01$) was found between the mean distance of Day 1 and Day 2. The $r = .97$ and the mean difference between Day 1 and Day 2 of -0.05 indicate that all the subjects tended to improve their performance on the second trial of the 12 minute run.

TABLE II

RELIABILITY AND REPRODUCIBILITY OF ANTHROPOMETRIC VARIABLES (N = 18)

Variable	Day 1			Day 2						
	$\overline{X}$	S	$SE_{\overline{X}}$	$\overline{X}$	S	$SE_{\overline{X}}$	$\overline{X}\Delta$	$SE_{\overline{X}\Delta}$	t	r
Height (cm)	166.1	6.0	1.4	166.1	5.9	1.4	0.0	0.1	0.39	1.00[a]
Weight (kg)	60.2	8.4	2.0	59.9	8.2	1.9	0.3	0.2	1.17	0.99[a]
BD (gm/cc)[b]	1.051	0.007	0.002	1.052	0.007	0.002	-0.001	0.000	1.36	0.98[a]
% Body Fat	20.6	2.2	0.6	20.3	3.1	0.7	0.3	0.2	1.41	0.98[a]
Fat Weight (kg)	12.5	3.2	0.8	12.4	3.3	0.8	0.1	0.1	1.55	0.99[a]
Fat Free Weight (kg)	47.8	5.6	1.3	47.7	5.2	1.2	0.1	0.2	0.89	0.99[a]

[a]Significant at $p \leq .01$.

[b]Body Density.

TABLE III

RELIABILITY AND REPRODUCIBILITY OF FIELD TEST VALUES

Variable	Day 1			Day 2						
	$\bar{X}$	S	$SE_{\bar{X}}$	$\bar{X}$	S	$SE_{\bar{X}}$	$\bar{X}\Delta$	$SE_{\bar{X}\Delta}$	t	r
12 Minute Run (n = 8)										
Distance (miles)	1.37	0.13	0.05	1.42	0.14	0.05	-0.05	0.01	4.54[a]	0.97[a]
Est. $\dot{V}O_2$ (l/min)	2.2	0.4	0.1	2.3	0.4	0.2	-0.1	0.0	3.0[b]	0.99[a]
Est. $\dot{V}O_2$ (ml/kg/min)	37.3	4.4	1.5	38.8	4.4	1.5	-1.5	0.4	3.7[a]	0.97[a]
600 Yard Run (n = 10)										
Time (sec)	132.2	13.9	4.4	131.1	16.5	5.2	1.1	2,2	0.5	0.91[a]
Est. $\dot{V}O_2$ (l/min)	3.0	0.4	0.1	3.0	0.4	0.1	0.0	0.0	1.5	0.98[a]
Est. $\dot{V}O_2$ (ml/kg/min)	50.4	3.3	1.1	50.8	4.1	1.3	-0.4	0.6	0.7	0.93[a]
Queens College Step Test (n = 10)										
Heart rate (b/min)	136.8	18.1	5.7	135.6	16.1	5.1	1.2	2.5	0.5	0.87[a]
Est. $\dot{V}O_2$ (l/min)	2.5	0.3	0.1	2.5	0.3	0.1	0.0	0.0	0.0	0.96[a]
Est. $\dot{V}O_2$ (ml/kg/min)	40.6	3.3	1.1	40.7	3.0	1.0	-0.1	0.4	0.4	0.92[a]

[a]Significant at $p \leq .01$.

[b]Significant at $p \leq .05$.

The results of this test compare favorably with others in the literature. The reliability coefficient ($r = .98$) found by Doolittle and Bigbee (1968) using nine ninth grade boys as subjects was similar to that found in the present investigation. Burris (1970), using a two-way ANOVA, found a consistency coefficient of .94 for the performance of the 12 minute run by 30 college females. Katch et al. (1973), using college females ($N = 36$), found an $r = .78$ which was lower than that of the present investigation.

The 600 yard run was a reliable ($r = .91$, $p \leq .01$) and reproducible ($t = .5$) measure in this investigation. The reliability coefficient for the Queens College Step Test, $r = .97$, was significant ($p \leq .01$) while $t = .5$ was not significant, indicating that the test was reproducible as well. The investigation of McArdle et al. (1972) yielded a similar reliability coefficient for the Queens College Step Test, $r = .92$, using 41 female subjects.

Balke-Ware Treadmill Test. The treadmill test variables measured were as follows: (1) heart rate (beats per minute) at which the test was terminated ($r = 0.00$), (2) $\dot{V}_e$ (l/min) ($r = .92$, $p \leq .01$), (3) temperature (^{o}C) ($r = .74$, $p \leq .05$), (4) respiratory exchange ratio (R) ($r = .28$), (5) $\dot{V}O_2$ (l/min) determined at the heart rate of 180 beats per minute ($r = .72$, $p \leq .05$), (6) $\dot{V}O_2$ (ml/kg/min) also determined from the heart rate of 180 beats per minute ($r = .67$), (7) duration of the test in minutes ($r = .72$, $p \leq .05$), (8) max $\dot{V}O_2$ (l/min) estimated from the duration of the test ($r = .75$, $p \leq .05$) and (9) max $\dot{V}O_2$ (ml/kg/min) also estimated from the duration of the test ($r = .75$, $p \leq .05$). The results of the treadmill test-retest are shown in Table IV. The heart rate produced an $r = 0.00$ since the first day testing yielded a standard deviation of 0.00 due to all the heart rates being 180 beats per minute. The respiratory exchange ratio produced a nonsignificant $r = .28$. This is similar to other studies such as that of McArdle et al. (1972), $r = .52$, which was also not significant. The $\dot{V}O_2$ (ml/kg/min) measured at the heart rate of 180 beats per minute was not a reliable measure for this investigation since $r = .67$. The max $\dot{V}O_2$ (l/min and ml/kg/min) estimated from the duration of the treadmill test was a reliable and reproducible measure ($r = .75$ for both, significant at $p \leq .05$). The study of McArdle et al. (1972) found the Balke-Ware Treadmill Test to be a reliable ($r = .95$) means for assessing the aerobic capacity (l/min) in women. McArdle et al. (1972) actually took the subjects to max $\dot{V}O_2$ rather than using the Balke-Ware prediction equation. No significant differences were found between the means of Day 1 and Day 2 for the Balke-Ware Treadmill Test variables.

Representative Values for Field Tests and Treadmill Test

Field test performance scores. Table V contains the representative field test values. For the 12 minute run, the mean distance run in 12 minutes was 1.34 miles. This mean was greater than that obtained in the investigation of Katch et al. (1973) using a group ($N = 36$, $\bar{X} = 1.22$ miles) of female varsity athletes ($n = 12$,

TABLE IV

RELIABILITY AND REPRODUCIBILITY OF TREADMILL TEST VALUES (N = 8)

Variable	Day 1			Day 2						
	$\bar{X}$	S	$SE_{\bar{X}}$	$\bar{X}$	S	$SE_{\bar{X}}$	$\bar{X}\Delta$	$SE_{\bar{X}}\Delta$	t	r
Heart Rate (b/min)	180.0	0.0	0.0	181.4	2.8	1.0	-1.4	1.0	1.40	0.00
$\dot{V}e$ (l/min)	49.1	11.6	4.1	52.3	14.7	5.2	-3.2	2.2	1.48	0.92[a]
Temp ($^{\circ}C$)	27.5	1.3	0.5	27.3	1.0	0.4	0.2	0.3	0.80	0.74[b]
R	0.94	0.90	0.03	1.00	0.08	0.03	-0.06	0.0	1.55	0.28
Measured $\dot{V}O_2$ (l/min)	1.9	0.4	0.1	1.7	0.4	0.2	0.2	0.1	1.38	0.72[b]
Measured $\dot{V}O_2$ (ml/kg/min)	31.0	6.7	2.4	28.3	5.0	1.8	2.7	1.2	1.53	0.67
Time (min)	16.4	2.7	1.0	16.4	3.4	1.2	0.0	0.9	0.00	0.72[b]
Est. $\dot{V}O_2$ (l/min)	2.3	0.4	0.1	2.3	0.4	0.1	0.0	0.1	0.27	0.75[b]
Est. $\dot{V}O_2$ (ml/kg/min)	38.6	5.9	2.1	38.8	6.7	2.4	-0.2	1.7	0.10	0.75[b]

[a]Significant at $p \leq .01$.

[b]Significant at $p \leq .05$.

TABLE V

REPRESENTATIVE FIELD TEST VALUES (N = 18)

Variable	$\bar{X}$	S	$SE_{\bar{X}}$	CV	Range
12 Minute Run					
Distance (mi)	1.34	0.13	0.03	9.7	1.13 - 1.50
Est. $\dot{V}O_2$ (l/min)	2.2	0.4	0.1	16.7	1.6 - 2.8
Est. $\dot{V}O_2$ (ml/kg/min)	36.3	4.4	1.0	12.2	29.2 - 41.6
600 Yard Run					
Time (sec)	135.3	12.4	2.9	9.1	113.2 - 155.0
Est $\dot{V}O_2$ (l/min)	3.0	0.4	0.1	12.3	2.3 - 3.5
Est. $\dot{V}O_2$ (ml/kg/min)	49.6	3.2	0.8	6.5	45.5 - 55.2
Queens College Step Test					
Heart Rate (b/min)	140.7	16.5	3.9	11.8	104.0 - 164.0
Est. $\dot{V}O_2$ (l/min)	2.4	0.4	0.1	16.7	1.8 - 3.3
Est. $\dot{V}O_2$ (ml/kg/min)	39.8	3.1	0.7	7.7	35.5 - 46.6

$\bar{X}$ = 1.30 miles), physical education majors (n = 10, $\bar{X}$ = 1.15 miles), and nonmajors nonvarsity (n = 14, $\bar{X}$ = 1.10 miles) as subjects. The mean value of 1.34 miles indicates, according to Cooper (1977), that the subjects used in this investigation were in good condition.

The mean time for the 600 yard run was 135.3 seconds. When this value was compared with the norms of the AAHPER Youth Fitness Test (1976) for females, 17 years of age and older, the subjects, as a group, were in the 95th percentile.

For the Queens College Step Test, the mean heart rate value was 140.7 beats per minute. This value was comparable to that of athletes (n = 6, $\bar{X}$ = 138 beats per minute) and approximately 15 beats per minute slower than the untrained subjects (n = 35, $\bar{X}$ = 155 beats per minute) used in the study by McArdle et al. (1972). The mean score ($\bar{X}$ = 140.7 beats per minute), when compared with the norms developed by McArdle et al. (1973), placed the subjects of this study in the 95th percentile.

Descriptive data from the Balke-Ware Treadmill Test. Table VI shows the descriptive data from the Balke-Ware Treadmill Test. The max $\dot{V}O_2$ ($\bar{X}$ = 2.3 l/min) estimated from the duration of the treadmill test was slightly greater than the max $\dot{V}O_2$ ($\bar{X}$ = 2.2 l/min) directly assessed with untrained females (n = 35) and less than that of athletes (n = 6, $\bar{X}$ = 2.7 l/min) in the study conducted by McArdle et al. (1972). The max $\dot{V}O_2$ value ($\bar{X}$ = 2.3 l/min) obtained in the investigation by Katch et al. (1973) was the same as for the present investigation. When the total group (N = 36) was subdivided into

TABLE VI

DESCRIPTIVE DATA FROM BALKE-WARE TREADMILL TEST (N = 18)

Variable	$\bar{X}$	S	$SE_{\bar{X}}$	CV	Range
HR (b/min)	180.3	1.2	0.3	0.7	180.0 - 185.0
$\dot{V}_e$ (l/min)	52.1	9.1	2.2	17.5	23.0 - 64.4
Temp (^oC)	27.6	1.2	0.3	4.2	26.0 - 29.0
R	0.99	0.09	0.02	9.1	0.84 - 1.13
$\dot{V}O_2$ (l/min)	1.8	0.3	0.1	16.7	1.1 - 2.2
$\dot{V}O_2$ (ml/kg/min)	29.7	5.0	1.2	16.7	22.6 - 40.5
Time	16.4	2.0	0.5	12.4	14.0 - 21.0
Est. $\dot{V}O_2$ (l/min)	2.3	0.3	0.1	13.5	1.6 - 2.9
Est. $\dot{V}O_2$ (ml/kg/min)	38.3	4.2	1.0	11.0	34.0 - 49.2

varsity athletes (n = 12), physical education majors (n = 10) and nonmajor-nonvarsity (n = 14) subjects, the max $\dot{V}O_2$ value ($\bar{X}$ = 2.3 l/min) for the present investigation was comparable to that of the physical education majors ($\bar{X}$ = 2.3 l/min), greater than the nonmajor-nonvarsity ($\bar{X}$ = 2.0 l/min), and less than the varsity athletes ($\bar{X}$ = 2.6 l/min).

When max $\dot{V}O_2$ was expressed in ml/kg/min, the mean value for untrained females in this investigation ($\bar{X}$ = 38.3 ml/kg/min) was comparable to that of the untrained females ($\bar{X}$ = 37.1 ml/kg/min) in the study by McArdle et al. (1972). The max $\dot{V}O_2$ value for athletes ($\bar{X}$ = 44.2 ml/kg/min) in the same study was greater than that found in the present investigation. In the study by Katch et al. (1973), max $\dot{V}O_2$ for the total group (N = 36) was 38.9 ml/kg/min, which was similar to the max $\dot{V}O_2$ estimated from the treadmill test in this investigation. The max $\dot{V}O_2$ value (ml/kg/min) was comparable to that of the physical education major ($\bar{X}$ = 37.5 ml/kg/min), larger than the nonmajor-nonvaristy ($\bar{X}$ = 35.4 ml/kg/min) and less than that of the varsity athlete ($\bar{X}$ = 43.7 ml/kg/min) subjects used by Katch et al. (1973).

Relationships Among Anthropometric Variables, Field Test Performance Scores and Estimated Max $\dot{V}O_2$ Values

The relationships among anthropometric variables, field test performance scores, and estimated max $\dot{V}O_2$ (l/min and ml/kg/min) were determined by the use of Pearson Product-Moment zero order correlation coefficients. Table VII shows the correlation coefficients between all the variables while Table VIII indicates the relationships among the four estimated max $\dot{V}O_2$ values (l/min and ml/kg/min).

Anthropometric variables. The relationship between height (cm), weight (kg), fat weight (kg), and fat free weight (kg) were significantly related ($p \leq .01$) to each other. The correlation coefficients between height, weight, and fat free weight were higher than those obtained by Katch et al. (1973). Percent body fat in the present investigation was significantly related to the other anthropometric variables at $p \leq .01$, except height, which was significant at $p \leq .05$. These findings are not in agreement with the findings of Katch et al. (1973) who indicated that height had a weak, negative relationship ($r = -.04$) with percent body fat.

Field test performance scores. The only two field test performance scores which were significantly related ($r = -.82$, $p \leq .01$) were the 12 minute run and the 600 yard run. The 12 minute run and the Queens College Step Test yielded an $r = -.01$ while the correlation coefficient between the 600 yard run and the Queens College Step Test was $r = -.27$.

The distance run in 12 minutes was not significantly related ($p \leq .05$) to height, weight, percent body fat, fat weight, or fat free weight. The findings of Katch et al. (1973) indicated that percent body fat and fat free weight were significantly related

TABLE VII

MATRIX OF ZERO ORDER CORRELATION COEFFICIENTS[a,b] FOR ANTHROPOMETRIC VARIABLES, FIELD TEST SCORES AND ESTIMATED MAX $\dot{V}O_2$ VALUES (N = 18)

Variable	1	2	3	4	5	6	7
1. Height (cm)							
2. Weight (kg)	.81						
3. % BF	.52	.77					
4. Fat Weight (kg)	.70	.94	.94				
5. Fat Free Weight (kg)	.80	.98	.64	.85			
6. $\dot{V}O_2$ (l/min)[c]	.54	.48	.23	.37	.56		
7. $\dot{V}O_2$ (ml/kg/min)[c]	-.04	-.27	-.39	-.35	-.16	.70	
8. 12 Minute Run (mi)	.19	-.13	-.30	-.23	-.11	.02	.10
9. Max $\dot{V}O_2$ (l/min)[d]	.78	.72	.41	.60	.71	.42	-.14
10. Max $\dot{V}O_2$ (ml/kg/min)[d]	.17	-.15	-.32	-.25	-.13	.03	.13
11. 600 Yard Run (sec)	-.29	-.10	.19	.07	-.14	-.01	.11
12. Max $\dot{V}O_2$ (l/min)[e]	.84	.89	.53	.74	.90	.44	-.24
13. Max $\dot{V}O_2$ (ml/kg/min)[e]	-.09	-.34	-.52	-.48	-.29	-.21	.01
14. Queens College Step Test (b/min)	-.23	-.02	-.01	-.06	.02	-.09	-.15
15. Max $\dot{V}O_2$ (l/min)[f]	.81	.89	.70	.86	.83	.41	-.22
16. Max $\dot{V}O_2$ (ml/kg/min)[f]	.23	.02	.01	.06	-.02	.09	.15
17. Max $\dot{V}O_2$ (l/min)[g]	.76	.72	.47	.64	.71	.60	.11
18. Max $\dot{V}O_2$ (ml/kg/min)[g]	.13	-.46	-.46	-.46	-.45	.13	.55

TABLE VII--Continued

	8	9	10	11	12	13	14	15	16	17	18
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											
9.	.59										
10.	1.00	.57									
11.	-.82	-.63	-.79								
12.	.28	.91	.25	-.54							
13.	.82	.27	.80	-.90	.12						
14.	-.01	-.04	-.04	-.27	.08	.27					
15.	-.15	.63	-.15	.06	.73	-.44	-.47				
16.	.00	.04	.04	.27	-.09	-.27	-1.00	.47			
17.	.11	.67	.10	-.13	.70	-.21	-.20	.71	.20		
18.	.30	-.14	.33	.04	-.36	.15	-.36	-.27	.36	.27	

[a] $r = .41$ is significant at $p \leq .05$.

[b] $r = .55$ is significant at $p \leq .01$.

[c] Measured at the heart rate of 180 beats per minute.

[d] Estimated from the results of the 12 minute run.

[e] Estimated from the results of the 600 yard run.

[f] Estimated from the results of the Queens College Step Test.

[g] Estimated from the duration of the Balke-Ware Treadmill Test.

TABLE VIII

ZERO ORDER CORRELATION COEFFICIENTS[a] FOR ESTIMATED MAX $\dot{V}O_2$ VALUES (N = 18)

Variable	Balke-Ware Estimate (l/min)[b]	Balke-Ware Estimate (ml/kg/min)[b]
12 Minute Run Estimate (l/min)[c]	.67	-.14
12 Minute Run Estimate (ml/kg/min)[c]	.10	.33
600 Yard Run Estimate (l/min)[d]	.70	-.36
600 Yard Run Estimate (ml/kg/min)[d]	-.21	.15
Queens College Step Test Estimate (l/min)[e]	.71	-.27
Queens College Step Test Estimate (ml/kg/min)[e]	.20	.36

[a] $r = .55$ is significant at $p \leq .01$.

[b] Max $\dot{V}O_2$ estimated from the duration of the Balke-Ware Treadmill Test.

[c] Max $\dot{V}O_2$ estimated from the results of the 12 minute run.

[d] Max $\dot{V}O_2$ estimated from the results of the 600 yard run.

[e] Max $\dot{V}O_2$ estimated from the results of the Queens College Step Test.

($p \leq .05$) to the distances run in 12 minutes. The correlations were $r = -.55$ and $r = .49$, respectively (Katch <u>et al</u>., 1973).

The 600 yard run performance score was not significantly related ($p \leq .05$) to the anthropometric variables measured for this investigation. Additionally, the heart rate recovery score of the Queens College Step Test was not significantly related ($p \leq .05$) with the anthropometric variables. The correlation coefficient, $r = -.02$ between body weight and the score from the Queens College Step Test, was lower than the $r = .15$ obtained by McArdle <u>et al</u>. (1972).

<u>Estimated max $\dot{V}O_2$</u>. The 12 minute run estimate of max $\dot{V}O_2$ (l/min) was significantly related ($p \leq .01$) to the max $\dot{V}O_2$ (l/min) estimated from the 600 yard run ($r = .91$) and the Queens College Step Test ($r = .63$). The estimates of max $\dot{V}O_2$ (l/min) from the 600 yard run and the Queens College Step Test were also significantly related ($r = .73$, $p \leq .01$). The 12 minute run estimate in ml/kg/min was significantly correlated ($p \leq .01$) with the 600 yard run estimate ($r = .80$) but not with the estimate derived from the Queens College Step Test ($r = .04$). The relationship ($r = -.27$) between the max $\dot{V}O_2$ (ml/kg/min) estimated from the 600 yard run and the Queens College Step Test was not significant ($p \leq .05$).

The relationships of max $\dot{V}O_2$ (l/min and ml/kg/min) estimated from the duration of the Balke-Ware Treadmill Test to the max $\dot{V}O_2$ (l/min and ml/kg/min) estimated from the field tests are shown in Table VIII. The max $\dot{V}O_2$ (l/min) estimated from the Balke-Ware

Treadmill Test was significantly related ($p \leq .01$) to the max $\dot{V}O_2$ (l/min) estimated by each of the field tests. When the estimations of max $\dot{V}O_2$ were expressed in ml/kg/min, none of the correlations were significant ($p \leq .05$).

The max $\dot{V}O_2$ (l/min) estimated from the Balke-Ware Treadmill Test was significantly related ($p \leq .01$) to each of the anthropometric variables. Expressing max $\dot{V}O_2$ in ml/kg/min reduced the significance of the correlations between max $\dot{V}O_2$, weight, percent body fat, fat weight and fat free weight to $p \leq .05$. The correlation between height and max $\dot{V}O_2$ (ml/kg/min) was reduced from $r = .76$ ($p \leq .01$) to $r = -.13$. In the investigation of McArdle et al. (1972) the relationship between body weight and max $\dot{V}O_2$ (l/min and ml/kg/min) was $r = .67$ and $r = -.46$, respectively. Both coefficients were significant ($p \leq .01$).

The max $\dot{V}O_2$ (l/min) estimated from each of the field tests was significantly related ($p \leq .05$) to the anthropometric variables measured in this investigation. When the max $\dot{V}O_2$ was expressed in ml/kg/min, only two relationships were significant ($p \leq .05$); the relationships between the max $\dot{V}O_2$ (ml/kg/min) estimated by the 600 yard run and the percent body fat ($r = -.52$) and fat weight ($r = -.48$).

ANOVA and Tuckey's w-Procedure

Analysis of Variance. A one-way ANOVA was used to determine if any significant differences existed between the means of the estimations of max $\dot{V}O_2$ in ml/kg/min (Table IX) and l/min (Table X).

TABLE IX

ANALYSIS OF VARIANCE OF MEAN DIFFERENCES OF MAX $\dot{V}O_2$ (ml/kg/min) ESTIMATED FROM FIELD TEST SCORES AND BALKE-WARE TREADMILL TEST

Source of Variation	df	Sum Of Squares	Mean Square	F-Ratio
Total	71	2867.19		
Among Groups	3	1896.69	632.23	44.30[a]
Within Groups	68	970.50	14.27	

[a]Significant at $p \leq .01$.

TABLE X

ANALYSIS OF VARIANCE OF MEAN DIFFERENCES OF MAX $\dot{V}O_2$ (l/min) ESTIMATED FROM FIELD TEST SCORES AND BALKE-WARE TREADMILL TEST

Source of Variation	df	Sum of Squares	Mean Square	F-Ratio
Total	71	15.41		
Among Groups	3	6.52	2.17	16.63[a]
Within Groups	68	8.89	.13	

[a]Significant at $p \leq .01$.

An F-ratio of 44.30 (significant at $p \leq .01$) indicated that there was at least one significant difference among the means of estimated max $\dot{V}O_2$ (ml/kg/min). A significant ($p \leq .01$) F-ratio was also computed for the comparison of max $\dot{V}O_2$ estimations expressed in l/min.

Tuckey's w-Procedure. To determine which means were significantly different, two Tuckey's w-Procedure post hoc analyses were conducted; one for max $\dot{V}O_2$ expressed in ml/kg/min and another for max $\dot{V}O_2$ expressed in l/min. The results of the analyses are shown in Tables XI and XII.

The post hoc analysis indicated, for max $\dot{V}O_2$ expressed in ml/kg/min, that the significant ($p \leq .05$) differences were between the means of the 12 minute run and the 600 yard run and the Queens College Step Test; the 600 yard run and the Queens College Step Test and max $\dot{V}O_2$ (ml/kg/min) estimated from the Balke-Ware Treadmill Test.

The second post hoc analysis to determine the significant differences between the means of estimated max $\dot{V}O_2$ (l/min) indicated that the 600 yard run estimate of max $\dot{V}O_2$ (l/min) was significantly different ($p \leq .05$) than each of the other estimations.

Multiple Regression Equations to Predict Max $\dot{V}O_2$ (ml/kg/min) in Untrained College Females

Estimation of max $\dot{V}O_2$ (ml/kg/min) from field test measures. Stepwise multiple regression procedures were used to determine which performance scores from the submaximal field tests investigated in

TABLE XI

RESULTS OF TUCKEY'S W-PROCEDURE FOR $\dot{V}O_2$ (ml/kg/min) (N = 18)

Group	$\bar{X}$	I 36.2	II 49.6	III 39.8	IV 38.3
I. 12 Minute Run	36.2	--	13.4[a]	3.6[a]	2.1
II. 600 Yard Run	49.6		--	9.8[a]	11.3[a]
III. Queens College Step Test	39.8			--	1.5
IV. Balke-Ware Treadmill Test	38.3				--

[a]Significant at $p \leq .05$; $w_{.05} = 2.8$

TABLE XII

RESULTS OF TUCKEY'S W-PROCEDURE FOR $\dot{V}O_2$ (l/min) (N = 18)

Group	$\bar{X}$	I 2.2	II 3.0	III 2.4	IV 2.3
I. 12 Minute Run	2.2	--	.8[a]	.2	.1
II. 600 Yard Run	3.0		--	.6[a]	.7[a]
III. Queens College Step Test	2.4			--	.1
IV. Balke-Ware Treadmill Test	2.3				--

[a]Significant at $p \leq .05$; $w_{.05} = .3$.

this study were best able to predict max $\dot{V}O_2$ (ml/kg/min) as estimated by the duration of the Balke-Ware Treadmill Test. The results of the analyses are shown in Table XIII. None of the three field test measures, the 12 minute run, the Queens College Step Test of the 600 yard run, yielded significant regression coefficients as single independent variables. The Queens College Step Test (Equation 1) had the highest correlation coefficient (.36) which accounted for 12.67% of the variance in max $\dot{V}O_2$ (ml/kg/min).

The multiple regression coefficient for the 12 minute run was significant ($p \leq .05$) when used in conjunction with the Queens College Step Test and the 600 yard run to predict max $\dot{V}O_2$ (ml/kg/min) (Equation 5). The inclusion of the two field tests with the 12 minute run increased the R (.30 to .59) and reduced the standard error of the estimation from 4.14 ml/kg/min with the 12 minute run to 3.74 ml/kg/min with the three tests combined.

<u>Estimation of max $\dot{V}O_2$ (ml/kg/min) from anthropometric variables and field test measures</u>. A stepwise multiple regression technique used to estimate max $\dot{V}O_2$ (ml/kg/min) from selected anthropometric variables and field test measures is presented in Table XIV. Equation 1 contained all four anthropometric variables, fat weight, height, fat free weight and weight, plus the three field test measures, the Queens College Step Test, the 600 yard run, and the 12 minute run. The coefficient of determination (R^2 x 100) for the four anthropometric variables and three field test measures indicated that 53.43 precent of the variation in max $\dot{V}O_2$ values

TABLE XIII

REGRESSION EQUATIONS ESTIMATING MAX $\dot{V}O_2$ (ml/kg/min) IN UNTRAINED COLLEGE-AGE FEMALES FROM MEASURES OF FIELD TESTS (N = 18)

Variable	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
Queens College Step Test (HR)	-0.09 (-0.36)[a]			-0.09 (-0.35)	-0.04 (-0.15)
12 Minute Run Distance (Mi)		9.39 (0.30)		9.33 (0.30)	28.41[d] (0.91)
600 Yard Run (Sec)			0.01 (0.03)		0.25 (0.74)
Y-Intercept	51.02	25.71	36.67	38.47	-28.37
R	.36	.30	.03	.46	.59
R^2 x 100[b]	12.67	8.98	.12	21.52	35.08
SEE[c]	4.05	4.14	4.33	3.97	3.74

[a]Standardized regression coefficients appear in parentheses beneath the unstandardized regression coefficients.

[b]Coefficient of determination.

[c]Standard error of estimate.

[d]Regression coefficient is significant at $p \leq .05$.

TABLE XIV

REGRESSION EQUATIONS ESTIMATING MAX $\dot{V}O_2$ (ml/kg/min) IN UNTRAINTED COLLEGE-AGE FEMALES FROM ANTHROPOMETRIC VARIABLES AND MEASURES OF FIELD TESTS (N = 18)

Variable	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 6[e]
Fat Weight	-1.82 (-1.38)[a]	-.46 (-.35)	-1.57 (-1.19)	-.75 (-.57)	-.75 (-.57)	-.64[d] (-.49)
Height	.31 (.44)	.28 (.41)	.51[d] (.73)	.33 (.47)	.44 (.64)	
Fat Free Weight	-1.20 (-1.59)	-.35 (-.47)	-1.28 (-1.70)	-.60 (-.80)	-.81 (-1.08)	
Weight	1.09 (2.18)		.87 (1.75)	.23 (.47)	.30 (.61)	
Queens College Step Test	-.01 (-.04)	-.07 (-.27)		-.06 (-.25)		-.10 (-.38)
600 Yard Run	.26 (.78)		.09 (.26)			
12 Minute Run	20.53 (.65)	2.90 (.09)				

TABLE XIV--continued

Variable	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5	Equation 6[e]
Y-Intercept	-60.05	19.57	-29.62	16.75	-5.68	60.07
R	.73	.67	.66	.66	.62	.60
R^2 x 100[b]	53.43	44.27	43.06	43.83	38.62	36.21
SEE[c]	3.74	3.74	3.78	3.75	3.77	3.58

[a]Standardized regression coefficients appear in parentheses beneath the unstandardized regression coefficients.

[b]Coefficient of determination.

[c]Standard error of estimate

[d]Regression coefficient is significant at $p \leq .05$.

[e]Regression equation is significant at $p \leq .05$.

(ml/kg/min) was accounted for by this linear combination of seven independent variables. The addition of the four anthropometric variables to the three field test measures increased the multiple correlation from R = .59 (Table XIII, Equation 5) to R = .73 and the coefficient of determination from 35.08 percent to 53.43 percent, while the standard error of the estimate remained constant (SEE = 3.74 ml/kg/min). In Equation 2, the weight and 600 yard run were deleted, decreasing R to .67 and the coefficient of determination to 44.27 percent. The standard error of the estimate (3.74 ml/kg/min) did not change with the deletion of the two variables.

Equations 3 and 4 contain the four anthropometric variables plus one field test measure each, the 600 yard run and the Queens College Step Test, respectively. The multiple correlation coefficients for the two equations were the same, R = .66, although the coefficient of determination for Equation 4 was slightly larger ($44.83 > 43.06$) and the standard error of the estimate slightly less ($3.75 < 3.78$).

Equation 5 included only the four anthropometric variables. This equation yielded an R = .62 and an SEE = 3.77 ml/kg/min. The coefficient of determination indicated that 38.62 percent of the variation in max $\dot{V}O_2$ values (ml/kg/min) was accounted for by a knowledge of the four anthropometric variables. This equation accounted for more variation ($38.62 > 35.08$) than did the combination of the three field test scores (Table XIII, Equation 5).

Equation 6 contains two independent variables, fat weight and the Queens College Step Test. By addition of the anthropometric variable fat weight to the Queens College Step Test (Table XIII, Equation 1), the R increased (.36 to .60), the coefficient of determination increased 23.54 percent (12.67 to 36.21) and the SEE decreased from 4.05 to 3.58 ml/kg/min.

Discussion of the Results

A number of investigations have been conducted to determine the response of the body to maximal and submaximal workloads (Åstrand and Ryhming, 1954; Taylor et al., 1955; Mitchell et al., 1958; Åstrand and Saltin, 1961a; Astrand and Saltin, 1961b; de Vries and Klafs, 1965). The information gained from these investigations has been used to develop submaximal field tests to assess an individual's aerobic capacity (Åstrand and Ryhming, 1954; Sloan, 1959; Balke, 1963; Skubic and Hodgkins, 1963; Cooper, 1968; McArdle et al., 1972). The majority of the research to determine the validity of submaximal field tests has involved the use of male subjects or well trained female subjects. An attempt was made in the present investigation to establish the validity of selected submaximal field tests to estimate the aerobic capacity of healthy untrained females. The field tests investigated were the 12 minute run, the Queens College Step Test, and the 600 yard run. The max $\dot{V}O_2$ estimated from the duration of the Balke-Ware Treadmill Test was used as the criterion of validity for this investigation.

The mean max $\dot{V}O_2$ values estimated by the duration of the Balke-Ware Treadmill Test were 2.3 l/min and 38.3 ml/kg/min (N = 18). These values were comparable to those obtained by McArdle et al. (1972), 2.2 l/min and 37.1 ml/kg/min for untrained female subjects (n = 35), but larger than the values obtained by Katch et al. (1973) of 2.0 l/min and 35.4 ml/kg/min (n = 14). Both these investigations used the Balke-Ware protocol with one modification. Rather than terminating the test at 180 beats per minute, the subject walked until she could no longer continue. The max $\dot{V}O_2$ value was computed as the highest $\dot{V}O_2$ value observed during the test. The estimated max $\dot{V}O_2$ values (l/min and ml/kg/min) may have been higher in the present investigation since the subjects were younger, taller, and heavier than the untrained subjects in the other two studies. Also, according to the results of the field tests, the subjects in the present investigation were in better physical condition.

It was hypothesized that there would be no significant differences found between the max $\dot{V}O_2$ determined by the Balke-Ware prediction equation and the max $\dot{V}O_2$ estimated from selected submaximal field tests. However, the results of a one-way analysis of variance (N = 18), revealed that at least one significant difference existed between the treadmill and field test estimations when expressed both in l/min and ml/kg/min. A Tuckey's w-procedure post hoc analysis indicated the significant difference was due to the same variable for both l/min and ml/kg/min, the 600 yard run.

This is not surprising since the equation used to estimate max $\dot{V}O_2$ from the 600 yard run was developed for use with 11 year old boys. There were no significant differences detected between the Balke-Ware estimate of max $\dot{V}O_2$ (l/min and ml/kg/min) and the 12 minute run estimate or the Queens College Step Test estimate.

It was also hypothesized that there would be a signficant relationship between performance scores of field tests and the max $\dot{V}O_2$ (l/min and ml/kg/min) estimated by the duration of the Balke-Ware Treadmill Test. Using a Pearson product-moment correlation technique, no significant relationships were found. Of the three field test performance scores, the Queens College Step Test had the highest correlation ($r = -.36$). This correlation was much lower than that found by McArdle et al. (1972) when constructing the test ($r = -.75$, $p \leq .01$). This was probably due to the mean recovery heart rate for the present investigation ($\bar{X} = 140.7$ beats per minute) being approximately 15 beats slower than the mean recovery heart rate ($\bar{X} = 155$) for the untrained subjects ($n = 35$) used by McArdle et al. (1972).

The relationship ($r = .30$) between max $\dot{V}O_2$ (ml/kg/min) estimated from the Balke-Ware equation and the 12 minute run was much lower than that found by Cooper (1968) ($r = .897$) or Katch et al. (1973) ($r = .67$). The difference between the correlations in the present investigation ($r = .30$) and in Cooper's (1968) ($r = .897$) was probably due to Cooper's sample having a wide age range (17-54 years) and large variations in max $\dot{V}O_2$ (31-59 ml/kg/min) and run scores (1.11 to 2.13 miles). In this study, the age range was 18.5 to 21.3 years, the max $\dot{V}O_2$ variation was 34.0 to 49.2 ml/kg/min and the 12 minute run scores ranged from 1.13 to 1.50 miles. When Katch et al. (1973) computed the correlations between max $\dot{V}O_2$ (ml/kg/min) and the 12 minute run for each subgroup (varsity, n = 12; physical education majors, n = 10; and nonvarsity-nonmajors, n = 14) they averaged r = .33. Katch et al. (1973) stated that the reduction in correlation was due to the increased homogeneity of the max $\dot{V}O_2$ and run scores within the subgroup. It is quite possible that the low correlations found in the present investigation between max $\dot{V}O_2$ (ml/kg/min) estimated by the duration of the Balke-Ware Treadmill Test and field test performance scores were low due to the small standard deviations and ranges for each of the tests.

An additional aim of this investigation, besides attempting to establish the validity of selected submaximal field tests, was to develop mutliple regression equations using anthropometric measures and performance scores as the independent variables. The equation which yielded the highest multiple correlation (R = .73) and coefficient of determination (53.43%) was the equation containing all seven variables; namely, the four anthropometric measures and the three field test performance scores. The negative signs in front of the regression coefficients indicated that as the variable increases (fat weight, fat free weight, and the Queens College Step Test score) the max $\dot{V}O_2$ (ml/kg/min) decreases. By deleting the 600 yard run and 12 minute run but keeping the Queens College Step

Test, the multiple correlation was reduced to .66 and the coefficient of determination to 43.83. The standard error of the estimate only increased from 3.74 to 3.75. The equation containing the 600 yard run plus the four anthropometric measures also had an $R = .66$ but the coefficient of determination was less than the equation containing the Queens College Step Test ($43.06 < 43.83$) and the SEE was greater ($3.78 > 3.75$). The equation containing the four anthropometric measures with the Queens College Step Test would be slightly more accurate and more easily administered than with the 600 yard run.

Even when no field test measures were added, the equation with four anthropometric variables yielded an $R = .62$, coefficient of determination of 38.62 and an SEE = 3.77. This indicates that, even without any knowledge of the field test performance scores, 38.62% of the variation in max $\dot{V}O_2$ (ml/kg/min) would be accounted for by the anthropometric variables.

When the equation was reduced to one anthropometric and one field test variable, fat weight and the Queens College Step Test were combined to yield an $R = .60$, a coefficient of determination of 36.21 percent and an SEE of 3.58. By the use of an F-ratio, this equation was found to be significant at $p \leq .05$.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of this investigation was two-fold. The primary purpose was to determine the validity of selected submaximal field tests used to estimate aerobic capacity. A secondary purpose was to determine the association of maximal oxygen consumption, as estimated from the duration of the Balke-Ware Treadmill Test, with the performance of selected submaximal field tests.

Eighteen healty untrained females, enrolled in the Fitness and Lifetime Activities Program at South Dakota State University, volunteered to participate as subjects for this investigation. The study was conducted from April 18 through May 11, 1979. The anthropometric data collected for each subject were height, weight, percent body fat, fat weight, and fat free weight. All the subjects were measured on two separate days to determine the test-retest reliability and reproducibility of the anthropometric variables. Each subject took four tests (the 600 yard run, the 12 minute run, the Queens College Step Test, and a treadmill test) plus two additional tests assigned at random to be used as retests (n = 8 for the 12 minute run and the Balke-Ware Treadmill Test, and n = 10 for the Queens College Step Test and the 600 yard run) to determine reliability and reproducibility. At least a one day rest was allowed between the testing sessions.

The data were statistically analyzed and summarized in seven parts. The first part included the test-retest reliability and reproducibility for all the data using the Pearson Product-Moment correlation technique and paired t-tests. The second and third parts compared the data in this investigation with other studies in the literature concerned with the 600 yard run, the 12 minute run, the Queens College Step Test and the Balke-Ware Treadmill Test. The fourth part showed the zero-order correlation coefficients among all the variables. Parts five and six contained analyses of variance used as a test of significance and the results of a Tuckey's w-procedure post hoc analysis, respectively. The seventh part showed stepwise multiple regression equations to predict max $\dot{V}O_2$ from the performance scores of the 600 yard run, 12 minute run, and Queens College Step Test. The statistical analyses were accepted as significant at the .05 or .01 level of probability. All statistical tests were conducted according to Morehouse and Stull (1975).

Findings of the Study

The findings of this study were as follows:

1. The test-retest reliability and reproducibility of the anthropometric variables ($r = .98$ to $r = 1.00$) were high enough to allow the use of only the first day measures in the subsequent statistical analyses.

2. All the anthropometric variables were significantly related to the max $\dot{V}O_2$ (l/min and ml/kg/min) estimated from the

duration of the Balke-Ware Treadmill Test except for the relationship between height and estimated max $\dot{V}O_2$ (ml/kg/min).

3. There were no significant differences found between max $\dot{V}O_2$ (l/min and ml/kg/min) estimated by the duration of the Balke-Ware Treadmill Test and that estimated by either the 12 minute run or Queens College Step Test.

4. A significant ($p \leq .05$) difference was found between max $\dot{V}O_2$ (l/min and ml/kg/min) estimated by the duration of the Balke-Ware Treadmill Test and that estimated by the 600 yard run.

5. The max $\dot{V}O_2$ (l/min) estimated by the duration of the Balke-Ware Treadmill Test was significantly related to each of the field test estimations of max $\dot{V}O_2$ expressed in l/min.

6. The max $\dot{V}O_2$ (l/min) estimated by the duration of the Balke-Ware Treadmill Test was not related to the field test estimations expressed in ml/kg/min.

7. When the Balke-Ware estimation of max $\dot{V}O_2$ was expressed in ml/kg/min, none of the field test estimations (l/min or ml/kg/min) were significantly related.

8. There were no significant relationships max $\dot{V}O_2$ (l/min or ml/kg/min) estimated from the Balke-Ware Treadmill Test and the 600 yard run score, 12 minute run score, or Queens College Step Test Score.

9. A significant ($p \leq .05$) regression equation could be developed using one anthropometric variable (fat weight) and one

field test performance score (the Queens College Step Test) to predict max $\dot{V}O_2$ (ml/kg/min).

Conclusions

The following conclusions were drawn relative to the hypotheses of the study and based on the findings of the investigation:

1. There is no significant difference between the Balke-Ware estimation of max $\dot{V}O_2$ (l/min and ml/kg/min) and the 12 minute run or Queens College Step Test estimates. There is a significant difference ($p \leq .05$) between the Balke-Ware estimation of max $\dot{V}O_2$ (l/min and ml/kg/min) and the 600 yard run estimate.

2. When expressed in l/min, max $\dot{V}O_2$ as estimated by the duration of the Balke-Ware Treadmill Test, is significantly related ($p \leq .01$) to the max $\dot{V}O_2$ estimated by each of the field tests.

3. There are no significant relationships between performance scores from selected submaximal field tests and the max $\dot{V}O_2$ (l/min and ml/kg/min) estimated by the Balke-Ware prediction equation.

Recommendations

In consideration of the results of this investigation the following recommendations are made:

1. A similar study be conducted using a sample with greater variation. The subject scores in this study had a small range and standard deviation, possibly contributing to the low correlations.

With greater variation, a sample more characteristic of the untrained condition might be obtained.

2. A similar study be conducted using a max $\dot{V}O_2$ test instead of a predicted max $\dot{V}O_2$ test. By using a max $\dot{V}O_2$ test, more accurate and reliable scores might be obtained.

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APPENDIX A

EXPLANATION OF TESTING PROCEDURES

COOPER 12 MINUTE RUN

The object of this test is to run as far as possible in the allotted 12 minutes. The track has been divided into four 55 yard segments. Your score will be recorded in laps plus .25 fractions of laps completed during the 12 minutes.

Only a standing start will be allowed. The timer will start the watch after saying, "Ready," "Go." During the test, you will be informed of your lap times. Although it is recommended that you run at a steady pace, walking is allowed if you feel it is necessary. Do not attempt to run the entire 12 minutes "all out." You are not being asked to run to total exhaustion.

At the end of 12 minutes, a whistle will be blown to signal the end of the test. Assistants will record your score after the 12 minutes have elapsed.

QUEENS COLLEGE STEP TEST

This test has been designed to measure the aerobic working capacity of college females. It entails continually stepping up and down on the bleacher step at the rate of 22 steps per minute, for three minutes. The test cadence is recorded and will be played during the test. With each beat, a step is to be taken (i.e., "Up," "Up," "Down," "Down").

You will be given a 15 second practice trial, followed by a three minute rest. Once rested, the step test will begin. At the end of the three minute test, you are to remain standing and I will take your pulse at the carotid artery for fifteen seconds.

Your score for the test will be your 15 second pulse rate multiplied by four to obtain your heart rate in beats per minute.

600 YARD RUN

The object of this test is to complete the 600 yard distance as quickly as possible. The starting and finishing lines will be marked off on the track. The distance is just over two and one half laps on the indoor track. Your score will be recorded in the seconds it takes to run the distance.

Only a standing start will be allowed. The timer will start the watch after saying, "Ready," "Go." During the test, you will be informed of your lap times. Although it is recommended that you run the entire distance, walking is permitted if you feel it is necessary.

As you cross the finish line, your score will be recorded.

BALKE-WARE TREADMILL TEST

The treadmill test entails walking on a treadmill at the speed of 3.3 miles per hour. For the first two minutes, the treadmill will remain level. After two minutes, the treadmill grade will be raised 2%; with each subsequent minute, the treadmill will be raised 1%. As you walk, your heart rate will be monitored and you will be breathing through a mouthpiece. At the heart rate of approximately 170 beats per minute, your expired air will be collected and analyzed for carbon dioxide and oxygen concentration. Once your heart rate reaches 180 beats per minute, the test will be terminated. If at any time during the test you feel that you are being overstressed, the test will be terminated.

APPENDIX B

HEALTH SURVEY FORM

NAME ______________________ ADDRESS ______________________

PHONE NUMBER ______________________

HEALTH SURVEY

HEALTH STATUS

Have you ever had . . . (If yes, give approximate date)

		YES	NO
1.	Rheumatic fever	____	____
2.	High blood pressure	____	____
3.	Heart murmur	____	____
4.	Any heart trouble	____	____
5.	Shortness of breath (not due to exertion)	____	____
6.	Heart palpitations	____	____
7.	Leg or ankle swelling (not due to injury)	____	____
8.	Coughing of blood	____	____
9.	Diabetes, high blood sugar, or sugar in the urine	____	____
10.	Any chronic illness	____	____
11.	Asthma, emphysema, or other lung condition	____	____

12. Do you smoke? _____ _____

    If so, how much? ____________

    For how long? ____________

13. Are you taking any medications? _____ _____

    If so, what type? ____________

    For how long? ____________

14. What is your present weight? _____

SYMPTOMS RELATED TO PHYSICAL EXERTION

Do you have . . . (If yes, give approximate date)

	YES	NO
1. Tightness or pressing pain in the chest, left side of the neck, or the left arm with exertion	_____	_____
2. Cough on exertion	_____	_____
3. Cramps in your legs when walking several blocks	_____	_____
4. Are you currently involved in any regular type of activity?	_____	_____

    If so, what activity? ____________

    How often? ____________

5. Have you been involved in any type of training program in the last six months?	_____	_____
6. Have you had a physical examination within the last year?	_____	_____

When?

7. Did any examination results indicate that your physical activity should be limited? ______ ______

   If so, explain: ____________________

   ____

TO BE DETERMINED BY THE INVESTIGATOR

1. % Body Fat ____________________

APPENDIX C

HUMAN CONSENT FORM

I, ______________________________, state that I am at least 18 years of age and am voluntarily participating in a program of research being conducted by Barbara A. Moran.

The purpose of the research is to investigate the validity of selected submaximal field tests to estimate the aerobic capacity of untrained females.

The project involves six testing sessions to be scheduled at a time mutually agreeable to the investigator and myself. During these sessions, data will be collected prior to, during, and immediately following the testing. The experimental procedures involve the collection of anthropometric data (height, weight, and skinfold measurements) and the recording of results from the Queens College Step Test, the 600 yard run, Cooper's 12 minute run, and the Balke-Ware Treadmill Test.

I acknowledge that I have been informed that I will be furnished with information about my test results. In addition, I understand that, upon request, I will be informed of how my test results compare with those of the group.

I acknowledge that I have read the description of the testing procedures and am aware of the possible risks. I understand that I may withdraw from participation at any time and will have any questions concerning the procedures answered by the investigator. I have read the foregoing and understand it. I freely and voluntarily consent to participate in this research project.

SIGNATURE OF VOLUNTEER ______________________________

SIGNATURE OF STAFF MEMBER ______________________________

DATE ____________________

APPENDIX D

MEASUREMENT OF HEIGHT

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Remove her sneakers and socks.

2. Stand erect with her back against the stadiometer, weight evenly distributed on both feet, heels together, eyes looking straight ahead and the arms hanging naturally at the sides.

3. Step off the stadiometer once the height is recorded and repeat the procedure two more times.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINES AND THEN:

1. Lower the metal bar of the stadiometer so that it is firmly on top of the subject's head.

2. Record the height to the nearest .5 centimeter.

3. Reset the stadiometer and repeat the procedure two more times.

THREE MEASUREMENTS ARE TO BE TAKEN AND RECORDED. THE AVERAGE OF THE THREE TRIALS WILL BE USED AS THE REPRESENTATIVE VALUE.

APPENDIX E

MEASUREMENT OF WEIGHT

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Remove her sneakers, socks, and any additional clothing other than her shorts and tee shirt.

2. Stand motionless in the middle of the scale's platform.

3. Once the weight has been recorded to the nearest .5 pound, step off the scale and repeat the procedure two more times.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINES AND THEN:

1. Move the weights so that the scale balances.

2. Once the scale stabilizes, record the weight to the nearest .5 pound.

3. Reset the scale to 0 and repeat the procedure two more times.

THREE MEASUREMENTS ARE TO BE TAKEN AND RECORDED. THE AVERAGE OF THE THREE TRIALS WILL BE USED AS THE REPRESENTATIVE VALUE.

APPENDIX F

SKINFOLD MEASUREMENTS

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Stand erect with her weight evenly distributed on both feet.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINE AND THEN:

1. Measure the triceps and suprailiac skinfolds on the right side of the body.
2. Grasp the skinfold sites between the thumb and fore-finger.
3. Apply the skinfold calipers approximately one centimeter below the fingers holding the skinfold.
4. Measure both skinfolds in the vertical plane.
5. Record the measurement to the nearest .5 centimeter and repeat the procedure two more times.
6. Measure and record three measurements from the following sites:

   a. Suprailiac: Vertical skinfold over the iliac crest in the mid-axillary line (Sloan and Weir, 1970).

   b. Triceps: Vertical skinfold on the back of the right arem, halfway between the acromion and olecranon processes (Sloan and Weir, 1970).

THREE MEASUREMENTS ARE TO BE TAKEN AND RECORDED. THE AVERAGE OF THE THREE TRIALS FOR EACH SITE WILL BE THE REPRESENTATIVE VALUE FOR THAT SITE.

APPENDIX H

12 MINUTE RUN TEST

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Stretch out and warm up until she feels ready to begin the test.
2. Only use a standing start.
3. Attempt to run at a steady pace to cover the most distance in the 12 minutes, but walking is permitted.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINES AND THEN:

1. Watch to be sure the subject only uses a standing start and starts from behind the starting line.
2. Start the watch after saying "Ready," "Go."
3. Let the subject know her lap times each time she passes the starting line.
4. Blow a whistle at the end of the 12 minutes and record the number of laps and .25 fractions of laps for each subject.

APPENDIX G

600 YARD RUN TEST

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Stretch out and warm up until she feels ready to start.
2. Only use a standing start.
3. Attempt to run the 600 yard distance as quickly as possible.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINES AND THEN:

1. Watch to be sure the subject only uses a standing start and starts from behind the starting line.
2. Start the watch after saying "Ready," "Go."
3. Let the subject know her lap times at 220 yards and 440 yards.
4. Stop the watch as the subject crosses the finish line.
5. Record the time to the nearest .1 second.

APPENDIX I

WOMEN'S AEROBIC FITNESS CLASSIFICATION (PREDICTED)*

Category		Measure	Age (Years) 13 - 19	20 - 29
I.	Very Poor	O_2 Uptake (ml/kg/min)	$>$ 25.0	$>$ 23.6
		12 Min. Distance (mi.)	$>$ 1.00	$>$ 0.96
II.	Poor	O_2 Uptake (ml/kg/min)	25.0 - 30.9	23.6 - 28.9
		12 Min. Distance (mi.)	1.00 - 1.18	.96 - 1.11
III.	Fair	O_2 Uptake (ml/kg/min)	31.0 - 34.9	29.0 - 32.9
		12 Min. Distance (mi.)	1.19 - 1.29	1.12 - 1.22
IV.	Good	O_2 Uptake (ml/kg/min)	35.0 - 38.9	33.0 - 36.9
		12 Min. Distance (mi.)	1.30 - 1.43	1.23 - 1.34
V.	Excellent	O_2 Uptake (ml/kg/min)	39.0 - 41.9	37.0 - 40.9
		12 Min. Distance (mi.)	1.44 - 1.51	1.35 - 1.45
VI.	Superior	O_2 Uptake (ml/kg/min)	$<$ 42.0	$<$ 41.0
		12 Min. Distance (mi.)	$<$ 1.52	$<$ 1.46

*Chart taken from: Cooper, K. H. The Aerobics Way, New York: M. Evans and Co., Inc., 1977. p. 281.

APPENDIX J

QUEENS COLLEGE STEP TEST

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Stretch out and warm up until she feels ready to begin the test.
2. Watch a demonstration of the test.
3. Practice the test for 15 seconds at the rate of 22 steps per minute.
4. Rest for three minutes.
5. Begin the test after hearing the first four beats of the tape.
6. Continue stepping on the bench at the rate of 22 steps per minute for three minutes.
7. Stop at the end of the tape and stand still while the investigator takes her pulse.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINES AND THEN:

1. Demonstrate the test for the subject.
2. Allow the subject a 15 second trial, using the taped sound of a metronome set at the rate of 88 beats per minute.
3. Have the subject rest for three minutes.
4. Begin the tape recorder with the metronome beat.
5. At the conclusion of the test, palpate the subject's carotid artery and count her pulse rate for 15 seconds, from 5 seconds to 20 seconds after the exercise.
6. Multiply the 15 second pulse rate by four and record the pulse rate in beats per minute.

APPENDIX K

BALKE-WARE TREADMILL TEST

THE SUBJECT SHOULD BE INSTRUCTED TO:

1. Report to the Human Performance Laboratory in shorts, tee shirt, and sneakers at the time scheduled.

THE ASSISTANT SHOULD INSTRUCT THE SUBJECT ACCORDING TO THE ABOVE GUIDELINES AND THEN:

1. Explain the Balke-Ware treadmill protocol:

   a. The subject will walk on the treadmill at the speed of 3.3 miles per hour. For the first two minutes, the treadmill will remain level. After two minutes, the treadmill grade will be raised 2%; with each subsequent minute, the treadmill grade will be increased 1% until the subject's heart rate reaches 180 beats per minute or the subject terminates the test.

   b. During the test, the subject will breath through a Modified Otis-McKerrow one-way valve.

   c. During each minute of the test, the subject's heart rate will be monitored by the use of two electrodes and a telemetric unit.

   d. When the subject's heart rate reaches approximately 170 beats per minute, expired gas samples will be collected and then analyzed for carbon dioxide and oxygen concentration.

2. Answer any questions the subject may have.

3. Put electrodes on the subject; one on the mid-sternum and the second in the fifth intercostal space.

4. Emphasize to the subject to stretch out, especially the calf muscles.

5. Have the subject try walking on the treadmill for two minutes at 3.3 miles per hour, 0% grade.

6. Let the subject rest for five minutes.
7. Begin the treadmill test.
8. Monitor heart rate for each minute.
9. When the heart rate reaches approximately 170 beats per minute, begin collecting expired gas samples and record $V_{e(ATPS)}$ and temperature (^{o}C).
10. Stop the test when the subject's heart rate reaches 180 beats per minute.
11. Analyze the expired gas samples with the Godart Pulmo-Analyzer.

APPENDIX L

INSTRUCTIONS FOR ANALYSIS OF EXPIRED AIR

USING GODART PULMO-ANALYZER

1. Fill Absorbers, large tubes with sodalime, small tubes with CaCl. Replace gauze wads at each end. No threads of gauze should be retained between plexiglass wall and neopreme caps.

2. Check absorbers before each test. Replace if necessary. Soda-lime turns violet in color when exhausted.

3. Switch on analyzer (mains and pump). Analyzer must warm up 60 minutes prior to any analysis.

4. Switch sensitivity to one and 5-way valve to zero position. Galvanometer should read zero.

MEASUREMENT OF CO_2 IN EXPIRED GAS

1. Set the MA meter at 150.

2. Set the 5-way value at zero position.

3. Set the sensitivity at 0.5.

4. Connect the sample bag at the in nipple. Open valve on bag.

5. Adjust the galvanometer to a deflection of 5 units by turning the electrical zero correction knob. A deflection to the left may now be regarded.

6. Wait until galvanometer is stable.

7. Set the 5-way valve CO_2 position. Pointer may jump 1 or 2 units.

8. Record meter reading where pointer is beginning to move steadily after the initial jump (e.g. 1.5).

9. Wait for stable reading and record deflection (e.g. 61.5). Deflection: 61.5 - 1.5 = 60

10. Reset 5-way valve to zero position. Pointer may again jump. Record meter reading where pointer is beginning to move back (e.g. 62).

11. Wait for stable reading and record deflection (e.g. 2). Deflection: 62 - 2 = 60

12. Determine 3 sets of readings for each sample tested. Calculate average value for each sample.

MEASUREMENT OF O_2 IN EXPIRED GAS

1. Set mA meter at 200.

2. Set the 5-way valve at zero.

3. Set the sensitivity at 1.0.

4. By turning zero adjustment knob, set needle at 100, then adjust needle to 98 so a deflection to the right can be regarded.

5. Wait until galvanometer is stable.

6. Set 5-way valve on O_2 position. Record meter reading where pointer is beginning to move back (e.g. 98.5) wait until meter is stable and record deflection (e.g. 53.5). Deflection: 98.5 - 53.5 = 45.

7. Reset 5-way valve to zero position. Record meter reading where pointer is beginning to move steadily (e.g. 54).

8. Wait for stable reading and record deflection (e.g. 99). Deflection: 99 - 54 = 45

9. Determine 3 sets of readings for each sample tested. Calculate average value for each sample.

10. Remove sample bag.

11. Reset to analyze next sample or turn off pulmo-analyzer if finished.

12. Empty absorbers when analyzing is completed for the day.

APPENDIX M

RAW DATA

Subject Number	Age	Height		Weight		Body Density		% BF	
		X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2
1	19.4	167.2	167.8	61.8	60.5	1.0500	1.0488	21.0	21.5
2	19.4	169.0	169.0	57.4	56.3	1.0545	1.0554	19.2	18.2
3	19.3	172.3	172.0	66.4	63.6	1.0587	1.0626	17.5	15.9
4	19.6	171.3	171.2	64.1	63.5	1.0460	1.0472	22.7	22.2
5	19.0	173.7	173.5	76.0	76.5	1.0453	1.0427	23.0	24.1
6	19.1	174.5	174.2	62.6	62.4	1.0468	1.0449	22.4	23.2
7	18.5	164.7	165.0	54.1	55.0	1.0584	1.0579	17.6	17.8
8	19.3	161.5	161.0	56.6	56.7	1.0519	1.0534	20.3	19.6
9	18.6	172.0	172.2	70.6	70.1	1.0386	1.0394	25.8	25.9
10	19.0	158.5	158.5	50.3	51.1	1.0588	1.0601	17.4	16.9
11	20.5	169.0	168.5	60.9	60.2	1.0535	1.0561	19.6	18.5
12	20.1	164.0	164.0	68.6	68.9	1.0449	1.0456	23.2	22.9
13	20.4	162.0	162.5	59.3	59.9	1.0489	1.0483	21.5	21.7
14	21.3	160.2	160.2	45.2	46.2	1.0634	1.0648	15.6	15.0
15	19.4	155.3	156.0	51.6	50.7	1.0548	1.0540	19.1	19.4
16	19.0	156.0	156.0	46.4	46.7	1.0545	1.0567	19.2	18.3
17	19.0	169.7	170.2	67.8	67.3	1.0415	1.0429	24.6	24.0
18	18.9	168.5	168.2	63.8	63.2	1.0508	1.0500	20.7	21.0

APPENDIX M--continued

Subject Number	FW		FFW		HR		$V_{e(ATPS)}$		Temp	
	X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2
1	13.0	13.0	48.8	48.5	180	180	58.0	62.0	29	28
2	11.0	10.2	46.4	46.1	185		53.0		29	
3	11.6	10.1	54.8	53.5	180		58.0		29	
4	14.6	14.1	50.0	49.4	180	181	55.0	51.0	26	27
5	17.5	18.4	58.5	58.1	180	180	59.7	60.5	28	27
6	14.0	14.4	48.6	48.0	180	180	51.0	62.0	29	28
7	9.5	9.8	44.6	45.2	180		45.0		27	
8	11.5	11.1	45.1	45.6	180		58.5		28	
9	18.2	17.9	52.4	52.2	180	180	47.0	53.0	26	27
10	8.8	8.6	41.5	42.5	180		54.0		27	
11	11.9	11.2	49.0	49.1	180		51.8		29	
12	15.9	15.8	52.7	53.1	180		64.4		27	
13	12.7	13.0	49.5	46.9	180	180	53.0	65.0	28	28
14	7.0	6.9	38.2	39.3	180	182	46.2	45.0	28	28
15	9.8	9.8	41.8	40.9	180		51.0		26	
16	8.9	8.5	37.5	38.2	180	180	23.0	20.0	26	25
17	16.7	16.6	51.1	51.2	180		62.0		28	
18	13.2	13.3	50.6	49.9	180		47.0		27	

APPENDIX M--continued

Subject Number	R		180 $\dot{V}O_2$ l/min		180 $\dot{V}O_2$ ml/kg/min		Time		Predicted $\dot{V}O_2$ l/min	
	X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2
1	0.84	1.01	2.2	2.1	36.3	34.8	17	16	38.7	37.1
2	0.99		1.7		30.3		17		38.7	
3	0.93		2.0		30.8		16		37.1	
4	1.01	1.05	2.0	1.6	31.4	25.1	14	12	34.0	30.7
5	1.10	0.98	2.0	2.3	26.6	30.2	14	13	34.0	32.4
6	0.98	1.06	1.9	2.0	30.4	32.0	20	20	46.2	46.2
7	1.00		1.6		29.0		17		38.7	
8	1.13		1.5		25.8		15		35.5	
9	0.92	1.00	1.6	1.7	22.7	24.2	15	13	35.5	32.4
10	1.09		1.5		29.6		19		43.2	
11	1.10		2.1		33.9		18		40.3	
12	1.05		1.8		26.2		17		38.7	
13	0.95	1.08	2.2	1.6	37.3	26.9	15	20	35.5	46.2
14	0.85	0.96	1.9	1.5	40.5	32.8	21	20	49.3	46.2
15	1.05		1.5		28.5		16		37.1	
16	0.90	0.84	1.1	0.9	22.6	20.6	15	17	35.5	38.7
17	1.00		2.0		29.0		16		37.1	
18	1.01		1.5		23.6		14		34.0	

APPENDIX M--continued

Subject Number	Predicted $\dot{V}O_2$ ml/kg/min X_1	X_2	12 min run (mi) X_1	X_2	$\dot{V}O_2$ l/min X_1	X_2	$\dot{V}O_2$ ml/kg/min X_1	X_2	600 yard run (sec) X_1	X_2
1	2.4	2.4	1.38	1.50	2.3	2.4	37.4	41.6	129.6	
2	2.2		1.25		1.9		33.5		139.9	137.5
3	2.5		1.47	1.50	2.6	2.7	40.5	41.6	115.8	115.3
4	2.2	2.0	1.23		2.1		32.5		139.3	
5	2.6	2.5	1.25	1.29	2.6	2.7	33.5	34.9	139.0	
6	2.9	2.9	1.41		2.4		38.4		133.8	
7	2.1		1.47	1.54	2.2	2.3	40.5	42.0	133.5	118.8
8	2.0		1.13	1.17	1.7	1.7	29.2	30.6	155.0	
9	2.5	2.3	1.23		2.3		32.5		144.8	
10	2.2		1.32	1.35	1.8	1.8	35.5	36.4	134.1	144.8
11	2.5		1.50		2.5		41.0		113.2	109.0
12	2.7		1.20		2.2		31.9		145.2	151.2
13	2.1	2.7	1.17		1.8		31.0		153.5	155.3
14	2.2	2.1	1.44		1.9		40.8		146.0	
15	1.9		1.17		1.6		30.6		142.6	136.4
16	1.6	1.8	1.47	1.50	1.9	1.9	40.5	41.6	125.2	
17	2.5		1.50		2.8		41.6		129.5	129.5
18	2.0		1.50	1.54	2.6	2.7	41.6	42.0	114.5	113.2

APPENDIX M--continued

Subject Number	$\dot{V}O_2$ l/min		$\dot{V}O_2$ ml/kg/min		QCST		$\dot{V}O_2$ l/min		$\dot{V}O_2$ ml/kg/min	
	X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2	X_1	X_2
1	3.1		50.5		148		2.4		38.5	
2	2.8	2.8	48.8	49.3	140	144	2.3	2.2	40.0	39.2
3	3.5	3.5	53.6	53.8	136		2.6		40.7	
4	3.0		47.7		148	156	2.5	2.4	38.5	37.0
5	3.5		46.1		120		3.3		43.7	
6	3.1		49.2		124	120	2.7	2.7	42.9	43.7
7	2.8	3.0	50.7	54.7	140		2.2		40.0	
8	2.6		45.7		148	148	2.2	2.2	38.5	38.5
9	3.2		45.6		112	116	3.2	3.1	45.1	44.4
10	2.6	2.5	51.3	48.8	160		1.8		36.3	
11	3.3	3.4	55.2	56.6	152	152	2.3	2.3	37.7	37.7
12	3.1	3.1	45.8	44.6	160	144	2.5	2.7	36.3	39.2
13	2.7	2.7	45.5	45.1	152		2.2		37.7	
14	2.3		49.6		104	108	2.1	2.1	46.6	45.9
15	2.5	2.6	49.2	50.7	136	136	2.1	2.1	40.7	40.7
16	2.5		54.6		144		1.8		39.2	
17	3.3	3.3	49.5	49.5	144	136	2.6	2.7	39.2	40.7
18	3.4	3.5	54.3	54.7	164		2.3		35.5	